Comprehensive Oyster Management Plan
Draft
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Executive Summary

The Comprehensive Oyster Management Plan (COMP) provides both a general framework and specific guidance for implementing a strategic effort to rebuild and manage native oyster populations in the Chesapeake Bay. The development of the COMP was a multi-partner endeavor by representatives from state and federal agencies, academia, environmental organizations and the oyster industry. Oysters are a vital component of the Chesapeake Bay ecosystem and provide important ecological functions and economic benefits. The main strategies for rebuilding native oyster populations and improving oyster management are: managing around disease; establishing sanctuaries; rebuilding habitat; increasing hatchery production; managing harvest; improving coordination among the oyster partners; and developing a database to track oyster restoration projects. Through these strategies, the COMP addresses one of the major commitments of the Chesapeake 2000, "By 2010, achieve a tenfold increase in native oysters in the Chesapeake Bay."

Currently, the major limiting factor for the oyster resource is the impact of diseases. Environmental conditions, especially temperature and salinity, affect the distribution and abundance of parasites that cause disease and make it particularly difficult to manage oyster restoration efforts. Recognizing that disease is the dominant factor in all restoration and repletion activities and that disease is correlated with salinity, comprehensive management strategies are defined according to three salinity zones. In addition, there are guidelines for reducing the impacts of disease and actions to enhance management practices such as criteria for moving seed. The disease management actions are utilized in all aspects of restoration activities, sanctuaries, hatchery production, and managing harvest.

A network of oyster sanctuaries that encompass at least 10% of the historically productive oyster grounds will be established throughout the Chesapeake Bay. Sanctuaries will be protected from harvest and, depending on salinity zone, will contribute to an increase in oyster biomass and possibly over time, contribute to the development of disease resistant broodstocks. Priority areas have been mapped and will be used to focus the multi-partner oyster restoration activities. Habitat will be rehabilitated in these protected areas to enhance oyster production. To support the restoration effort, hatchery production will be increased. Sanctuaries are one of the main strategies for regulating the fishery. Harvest will also be regulated by a relatively new initiative, special management areas (reserves). These areas will be opened and closed on a rotational basis. This strategy is expected to delay harvest till the oysters reach a larger size, thereby, increasing ecological and economic value.

Monitoring results are currently used to guide restoration and repletion activities. With the proposed scope of restoration activities over the next decade, monitoring needs will increase. The oyster partners will form a technical committee to develop guidelines for data management and develop a database for tracking oyster restoration projects. Cooperation among multiple agencies and organizations is essential for implementing the COMP and effectively utilizing limited resources.

Reaching the desired objectives is a multi-generation, long-term effort and there are no guarantees the objectives will be met. Given the current status of disease and present environmental conditions, progress towards increased oyster biomass may not occur in the short-term. The challenge is great, but the potential benefits in both ecological and economic terms are also great. The COMP proposes to guide, focus, and coordinate the multiple partners in rebuilding the native oyster population in Chesapeake Bay.

I. INTRODUCTION

Since the inception of the Chesapeake Bay Program, restoring the Bay's valuable oyster resource has been a high priority. The adoption of the Chesapeake 2000 Agreement marked the beginning of a renewed effort to rebuild the Bay's native oyster resource. The purpose of the Comprehensive Oyster Management Plan (COMP) is to provide both a general framework and specific guidance for implementing a strategic, coordinated, multi-partner management effort. Representatives from state and federal agencies, academia, environmental groups, and the oyster industry developed the plan (for a complete list and description of the oyster partners, refer to Appendix 1). There are six main strategies for rebuilding and managing native oyster populations: establishing oyster sanctuaries; rebuilding habitat; managing harvest; increasing hatchery production; improving coordination among the oyster partners; and developing a database to track restoration projects. The COMP endeavors to improve and complement the on-going efforts of multiple oyster partners towards restoration in the Chesapeake Bay. Currently, the major impediments to rebuilding the oyster resource are the impact of diseases and the degraded condition of oyster habitat. The magnitude of these impediments cannot be over-emphasized and will be repeated throughout the document.

About This Plan

Over the years, the Chesapeake Bay Program and its partners have developed several plans to manage the oyster fishery and address oyster habitat. A Chesapeake Bay Oyster Management Plan was adopted in 1989 and revised in 1994. The Chesapeake Bay Aquatic Reef Habitat Plan was completed in 1994 and addressed restoring oyster habitat. The 2002 Comprehensive Oyster Management Plan:

- addresses both habitat restoration and fishery management in one cohesive document;
- emphasizes biologically based, strategic decision making;
- enables an adaptive management approach; and
- provides better coordination among key agencies, organizations, and institutions involved in the oyster restoration effort.

Vision and Perspective

A restored oyster resource can be described as abundant, self-sustaining, occurring over a wide range throughout the Chesapeake Bay, providing important ecological services, and supporting an oyster fishery. In order to attain both ecological and socioeconomic objectives, compromises will be necessary because since they can be in opposition to one another.

The extensive reefs that gave the Chesapeake Bay its original name, *Tschiswapeki* or "Great Shellfish Bay,"

DESIRED BENEFITS

A restored oyster resource will:

- produce more oysters than are removed each year by natural mortality and harvest.
- improve water clarity by filtering phytoplankton and sediment from the water.
- provide ecologically valuable reef habitat for crabs, fish, and other organisms.
- provide income for water-dependent families and communities.
- generate additional revenue from processing, shipping, and secondary sales of oyster products.

developed over the course of ten thousand years. Since the 1860's, fishing and habitat destruction combined with the last few decades of disease have reduced native oyster populations to the current low levels. Achieving a restored oyster resource will not be easy, and will require substantial financial and manpower commitments over several decades

It is unknown how large the Bay's oyster populations must be to satisfy the vision of a restored oyster resource and deliver the desired ecological and economic benefits. Although the objective of a tenfold increase in oysters is ambitious, it represents only a fraction of historic levels of oyster abundance. Since the Chesapeake Bay ecosystem and its watershed have been drastically altered by human activities over the past centuries, it is probably not possible to restore oysters to historic levels. It is more realistic to view the tenfold objective as the first step toward a restored oyster resource. Over the years, knowledge has been gained on oyster restoration techniques and applied in a meaningful way. With the impacts of disease and its recent expanded distribution, more challenges have arisen in regards to oyster restoration and harvest. There is a need to systematically expand our knowledge base and adapt management strategies to reduce the impact of disease. In addition to recognizing the natural and economic limitations, there needs to be expansion of partnerships to improve the effectiveness of large-scale, bay-wide oyster restoration. Reaching the desired objectives is a multi-generation, long-term effort and there are no guarantees the objectives will be met. Given the current status of disease and present environmental conditions, progress towards increased oyster production may not occur in the short-term. The challenge is great but the potential benefits, in both ecological and economic terms, are also great.

Objectives

Objective 1: Increase oyster populations to levels that restore important ecological functions, including:

- water filtration and nutrient cycling;
- habitat creation for organisms such as oysters, finfish, crabs, and a diversity of other species; and
- adequate broodstock to sustain regional populations.

It is widely recognized that oysters and oyster reefs are vital components of the Chesapeake Bay ecosystem, and their restoration is an essential element in the ecological rehabilitation of the bay. Accordingly, this objective emphasizes the need to focus on ecological functions in judging the long-term success of restoration efforts. In order to achieve the primary ecological objective, the plan commits to the following:

1a): Achieve a tenfold increase in oyster biomass by 2010, relative to a 1994 baseline.

This is an interim value for rebuilding oyster populations, which comes from the commitment made by signatories to the Chesapeake 2000 Agreement: "By 2010, achieve, at a minimum, a tenfold increase in native oysters in the Chesapeake Bay, based upon a 1994 baseline. By 2002, develop and implement a strategy to achieve this increase by using sanctuaries sufficient in size and distribution, aquaculture, and other management approaches necessary to achieve this objective." The tenfold increase will be measured in terms of oyster biomass. Biomass is considered a better indicator of population status and ecological function than abundance because large oysters contribute significantly more to reproduction and water filtration than do small oysters. It is expected that disease mortality will impede the attainment of this objective.

1b): Rebuild habitat by constructing new reefs on appropriate bottom type; considering environmental conditions; and, increasing production from remaining reefs.

Oyster reefs as they occurred historically, no longer exist in Chesapeake Bay. Many of the areas are remnants of the historic reefs. The spatial extent of loss and degradation is difficult to quantify but depositing cultch and keeping it free from sediment are critical tasks for successfully rebuilding the oyster resource. Available, clean substrate is necessary for larval settlement and consequent oyster production.

1c): Conserve 10% of the historically productive oyster grounds as permanent sanctuaries.

The baywide commitment to protect and preserve areas for rebuilding the oyster resource is based on fundamental conservation principles. Protecting a portion of the wild resource (e.g., habitat, population, and community) is a basic tenet of stewardship for any exploited, renewable resource. The 10% figure emerged as a consensus statement from a workshop on oyster restoration held in January 2000. The workshop participants agreed to set aside, restore, and protect oyster bottom habitat. It is unknown whether protecting 10% of the historic bottom will be enough to detect enhanced ecological function in the Bay or if protecting broodstock in sanctuaries will enhance spat settlement. Maryland and Virginia have identified priority regions within the Chesapeake Bay to focus restoration activities. This objective will be closely monitored over the next decade to evaluate its effectiveness and determine if protecting more areas is needed.

Objective 2: Achieve a sustainable oyster fishery through a combination of harvest from public oyster grounds and private aquaculture.

This objective reflects the economic and social value associated with commercial oyster production in Chesapeake Bay. It represents a decision to allocate limited resources between two different, and sometimes conflicting, uses. By committing to a fishery, attaining the tenfold increase in oyster biomass may take longer. Hatchery production will be increased and aquaculture will be encouraged to augment oyster production.

Objective 3: Reduce the impacts of disease on oyster populations.

The parasites, *Haplospiridium nelsoni* (MSX) and *Perkinsus marinus* (Dermo) that cause disease, are one of the major limiting factors to rebuilding the oyster resource and attaining the 10-fold increase in oyster biomass. Environmental conditions, especially temperature and salinity, affect the distribution and abundance of parasites that cause disease and make it particularly difficult to manage oyster restoration efforts. In the past, the spread of disease may have been facilitated by management practices. Strategies to manage around the disease problem must be conservative. This objective is focused on understanding and ameliorating factors that reduce the prevalence and intensity of disease to the greatest extent possible.

Objective 4: Increase hatchery production and develop disease resistant strains.

One approach to rebuilding oyster populations is increased hatchery production of oyster spat. Although hatcheries will never match the potential of wild oyster populations, hatchery production could play an important role in re-establishing oyster populations in depleted areas. Hatchery operations also have the potential to selectively breed oysters that are disease-resistant.

Feasibility of reaching the 10-fold increase in biomass

Given the challenges of oyster disease, degraded habitat and fishing pressure, how feasible is a tenfold or greater increase in native oysters in Chesapeake Bay? On a site- or tributary-specific basis, the answer is that habitat rehabilitation and oyster stocking can result in increases greater than tenfold. For example, oyster populations in the Severn and Magothy Rivers have shown increases on the order of 100 fold as a result of recent sanctuary restoration projects. However, the low spat settlement typical of low salinity tributaries means that re-stocking will be required to maintain the newly established populations. The length of time for the area to be self-sustaining is unknown. Spatially explicit population dynamic models that include the major factors influencing mortality and recruitment rates across multiple salinity regimes, are needed to help answer the question.

Maryland

The best available evidence suggests that approximately 100,000 acres were historically productive oyster habitat in Maryland. Estimates derived from growth and mortality rates measured by Maryland's Fall Oyster Survey over the past fifteen years suggest that restoration of 10,000 acres may be sufficient to achieve a tenfold increase in oyster biomass. This estimate involves certain assumptions, such as planting oysters at high densities (2 million spat per acre) and a continuation of the same long-term averages in growth and mortality that have occurred in the recent past.

Another way to estimate the level of effort needed to obtain a tenfold increase in oysters is to consider increasing the amount of productive habitat by tenfold. The estimate of currently productive oyster grounds in Maryland is 1% of the historic Yates grounds (100,000 acres), or 1,000 acres. A tenfold increase would be 10,000 acres, the same figure obtained independently by extrapolation from average growth and mortality rates.

Virginia

In Virginia, the combined threats of disease in high salinity areas and freshets in low salinity areas have significantly reduced the amount of potentially restorable oyster habitat. The highest probability of success for establishing stable, multi-year class oyster populations lies in areas between the spatial boundaries set by disease and freshets. There are few places where stable oyster populations might realistically be re-established because these boundaries shift in both space and time. There are no areas in Virginia waters that are absolutely inviolate to either freshet or disease. In very dry years the disease limit can extend upstream as far as the freshet limit will extend downstream in wet years.

Increasing the number of oysters in Virginia waters depends upon a cumulative probability function, the outcome of which cannot be predicted. This probability is dependent upon three major factors: 1) location of effort in regions of lowest susceptibility to disease and/or freshet impact, 2) location of effort in regions of historically high recruitment that remain in proximity to extant broodstock populations, and 3) the ability to encourage multiple rather than single year class recruitment events to deployed shell substrate and thereby support establishment of populations with multiple year classes. While items (2) and (3) are subject to potential improvement by strategically placed habitat rehabilitation efforts, the underlying drivers for item (1) are random variables beyond human control. It is important to point out, however, that even small gains, such as those promised by recent work on breeding disease resistant strains of the native oyster, could shift the probability function in a more positive direction.

Comprehensive Oyster Management Plan Content

There are six main components to rebuilding and managing the native oyster population in the Chesapeake Bay: 1) establish sanctuaries that protect oyster populations from harvest and implement restoration projects based on salinity zones; 2) rebuild oyster habitat; 3) implement harvest strategies; 4) increase hatchery production; 5) improve coordination among the oyster partners; and, 6) develop a database to track oyster restoration projects. All strategies consider the impacts and limiting factors associated with disease. The Plan provides guidance on restoration areas and a standardized approach to implementing restoration projects. Special management areas will be implemented to enhance ecological functions and obtain better market values for the oyster industry. In order to assess the status of the oyster resource, track restoration efforts, and evaluate management strategies and actions, an information network will be established. A database will be developed which will allow the oyster partners to interact in a timely manner, contribute research results, and exchange monitoring information.

The second part of the plan provides guidance on implementing oyster restoration projects including plan content, review, and evaluation. The guidance applies to any restoration project including but not limited to sanctuaries, special management areas, and repletion programs. It includes site selection and site suitability criteria. The second section also includes a glossary of terms. In addition, there are two appendices. The first appendix identifies and describes the roles of the major oyster partners. The second appendix identifies the links to other Chesapeake Bay Program activities.

II. STRATEGY OVERVIEW

Recognizing that disease is the dominant factor in all restoration and *repletion* activities and that disease is correlated with salinity, comprehensive management strategies will be defined according to three salinity regions; high, moderate and low. The boundaries of the low and high salinity zones are relatively well defined, except in extreme climatic events (e.g. drought); while the boundaries of the moderate zone fluctuate annually. In order to produce visual representations, i.e., maps of each salinity zone, the following methodology was utilized. Salinity data from the Chesapeake Bay Program was averaged from 1990-1999 at depth between 10-20 feet. Two seasons are represented, spring (April-June) and summer (July-September). Different management actions pertaining to the three strategy components will be considered for each zone (Figure 1, 2). As estuarine organisms, oysters exist under a wide range of environmental conditions. In any given area, a particular oyster bar, river system, or region is subject to change, especially due to rainfall patterns. During periods of abnormal rainfall, characteristics of the zones as defined in this document may be dramatically altered. Actions outline for individual zones are based on long-term salinity patterns and are subject to modifications as environmental conditions dictate.

Zone 1

Zone 1 is the lower salinity water of Chesapeake Bay between 5ppt and <12ppt. This zone generally encompasses the portion of the Bay above the Bay Bridge in Maryland, and the upper reaches of the Potomac, Choptank, Chester, Patuxent and other tributaries in Maryland. Virginia has virtually no *public oyster grounds* designated within the lower salinity zone.

Relative to the other zones, Zone 1 is characterized by lower disease and better survival, but low reproduction capability. Restoration efforts will depend on *seed plantings* to increase populations. Disease exists in this zone but low salinity reduces the impact of disease. There is less mortality and oysters live longer. However, because of the decreased salinity *spat settlement* is very low, often non-existent. To increase the oyster population, this area is dependent on either natural or *hatchery seed*. Expectations are that oysters in this zone will contribute significantly to the short- term, 10- fold objective and long-term biomass accumulation.

Zone 2

Zone 2 is generally classified as 12-14 ppt and has fluctuating boundaries based on climatic variation of wet and dry years. Although Zone 2 appears to be a rather narrow salinity range, it actually encompasses a broad geographic area. This zone experiences a range of spat settlement from low to moderate to high due to fluctuating environment parameters. Disease mortality also fluctuates, generally increasing during drought years and decreasing during wetter periods. When disease mortality lessens, this zone can experience rapid recovery of populations and biomass due to increased survival in combination with successful *recruitment*. The reverse can also happen just as quickly. Public oyster grounds and restoration activities that occur within this area will have varying results depending on environmental and disease conditions. Any oyster projects in this zone should be carefully considered on an annual basis.

Zone 3

Zone 3 is the highest salinity region of the Chesapeake Bay with greater than 14ppt. This zone comprises a large portion of the Bay and most of Virginia waters. There is continuous disease pressure from both parasites. As a result, there is generally heavy disease-related mortality and few oysters survive to market size. Those oysters that do survive beyond 3-4 years in this region may presumptively be *disease resistant*. This area favors spat settlement and there is a greater probability of yearly spat settlement events, which provides a fairly constant influx of new oysters to the zone. This zone does not experience the dramatic rebounds that are possible in Zone 2 due to constant high levels of disease mortality. Augmenting biomass will be a challenge in Zone 3. More aggressive restoration techniques involving stock enhancement with selectively bred oysters will be required. Restoration sites will require adaptive management and extensive maintenance. This zone is not expected to significantly contribute to the short- term objective of a 10-fold increase but it may contribute to the long-term objective of developing *disease resistance* in native oysters. This result will be far beyond the timeframe of this plan.

Adaptive Management

The oyster partners have practiced and will continue to practice, a policy of adaptive management. Before any oyster project is implemented in the Chesapeake Bay, the results of previous efforts will be considered to formulate the best approach for each project. With the adoption of the COMP, the partners agree to utilize the best available data to obtain the greatest level of success from each project and from all the projects collectively. The essential elements of adaptive management that will be practiced are briefly described below.

Project Design

Projects will be designed to provide as much information as possible about the performance of methods used. Project proponents will explicitly consider how a proposed project can help test the efficacy of available methods and management options or develop new ones.

Measurable Objectives

All projects will have clearly defined, measurable objectives that relate directly to one or more of the objectives for oyster restoration presented in chapter I. These objectives will be translated into success criteria, measures by which the project will be evaluated.

Strategic Decision Making

Considerations of oyster biology, potential for project success, and contribution to overarching objectives will form the basis for decisions about where and how to invest limited resources. The oyster partners will need to consider if a collective and focused effort would be more strategic for accomplishing the objectives of the Plan than individual efforts. Unifying efforts in a selected area may yield greater results than a series of scattered individual projects over a broader area. Targeting decisions will need to be made regarding the various salinity zones and even tributaries within preferred zones. Electronic synthesis (GIS) of relevant data – salinity, bottom, environmental conditions, spat settlement history, disease, etc will aid in the decision making process

Project Review Process

Partners and stakeholders will participate in the review of proposed project plans and site designations through an ongoing review process. In Maryland, the review will be a joint process, which involves Department of Natural Resources (DNR), the Maryland Oyster Roundtable (ORT), and the ORT Scientific Advisory Committee (ORSAC). The equivalent review in Virginia will be coordinated by Virginia Marine Resources Commission (VMRC) and includes Virginia Institute of Marine Science (VIMS), Virginia Department of Environmental Quality (VADEQ), and Army Corps of Engineers (ACOE). As the National Oceanographic and Atmospheric Administration (NOAA) proposes to support oyster restoration activities, both financially and technically, they will be a major partner in the review process. Current review processes for Maryland and Virginia are detailed in Section 2, chapter I.

Monitoring

Limited man-power and funding require that project-specific and bay-wide oyster monitoring are done in a manner that effectively utilizes those resources. Project budgets need to include sufficient resources for monitoring in order to adequately measure and report the results of the project. The amount of funding allocated for monitoring is dependent on the size of the project and the project objectives. Project monitoring should be customized not only to the project's objectives but also to the area or region where it is completed and include a timeframe. A bay wide monitoring program to assess *stock* status including disease, is currently being developed through a joint Maryland/Virginia project and scheduled for completion in 2003. Data will be collected in a standardized format so projects are comparable and each state will maintain oyster data in compatible databases (see Chapter VII).

Evaluation

Results of projects will be shared among the restoration partners through the ongoing project review process, as well as by the development of information management systems and an annual review symposium (see chapter VII). These mechanisms for sharing project results will allow partners to evaluate what worked and did not work, what methods need to be modified, and the "next steps" that can be taken to improve restoration and management practices.

III: Oyster Disease

Introduction

The biggest challenge to oyster restoration in the Chesapeake Bay is to overcome the impacts of disease. There are at least fourteen different diseases and parasites documented for the eastern oyster (Ford & Tripp 1996). Two oyster protozoan (single-celled) parasites, *Perkinsus marinus* (Dermo) and *Haplosporidium nelsoni* (MSX), are currently the major sources of oyster mortality in the Chesapeake Bay. Environmental conditions, especially temperature and salinity, affect the distribution and abundance of the parasites (Burreson & Ragone Calvo, 1996). In addition, they affect how parasites are transmitted, their prevalence (how many hosts are infected) and their intensity (how severe the infection) (Andrews & Wood, 1967; Reece et al., 2001). Environmental conditions that affect temperature and salinity, especially climatic and seasonal changes, make it particularly difficult to manage oyster restoration efforts in the presence of disease. The best management practices can be negated by naturally occurring events. The opposite results are also possible. Environmental conditions can favor oyster growth and reproduction, and disease can abate. During the late 1980s and early 1990s, significant changes in the distribution of pathogens in the Chesapeake Bay occurred as a result of four years of drought conditions and warm winters (Burreson & Ragone Calvo, 1996). Currently, P. *marinus* is present on all productive oyster grounds in the Bay. Successful management strategies for rebuilding the oyster population in Chesapeake Bay must consider the life history of the pathogens, the effects of environmental conditions, and methods to increase recruitment.

Dermo

Although *Perkinsus marinus* is endemic to the Atlantic coast from Virginia to the Gulf of Mexico, it has expanded its range in Maryland and along the coast to Maine over the last ten to fifteen years (Reece et al. 2001). Originally, P. marinus occurred only in higher salinity waters of the Bay (>15 ppt). The occurrence of the parasite in lower salinity areas of the Bay is a result of environmental conditions and possibly transplanting infected oysters from one area to another (Burreson & Andrews 1988). Evidence from Delaware Bay suggests that the spread of disease is also linked to recent warming trends in climate (Ford 1996). Under the current climatic conditions of low rainfall, drought and high disease levels, movement of infected oysters into lower salinity regions may be counter-productive. Exposure to low salinity conditions (<12 ppt) decreases the virulence of *P. marinus* infections, but does not eliminate the parasite from natural seed oysters. Under drought conditions, natural seed oysters in these areas experience higher mortality rates. Under normal conditions of lower salinity,

OYSTER DISEASE ISSUES

Can disease prevalence be minimized in low to moderate salinity regions?

Can disease-resistant strains be used to establish stable populations in high salinity regions?

Can the genetic basis of disease resistance be conserved when placed in the wild?

natural seed oysters would experience lower mortality. Restoration efforts under the latter conditions would have a better chance of being more successful.

The natural dynamics of parasite transmission are poorly understood (Burreson & Ragone Calvo, 1996). Laboratory experiments have documented that *P. marinus* is transmitted directly from one oyster to another (Andrews 1988). Infective stages of *P. marinus* are distributed in the water column and encountered while oysters are feeding. *Perkinsus marinus* rapidly reproduces and kills heavily infected oysters at temperatures above 25°C (77°F). *P. marinus* mortality is size-selective with peak mortality occurring at around 75mm (3 inches) (S.Jordan, per comm). When death occurs, oysters release *P. marinus* into the water column and another round of infection is initiated (Ford & Trip 1996).

MSX

Haplosporidium nelsoni, is a non-native parasite that first caused extensive mortality in Chesapeake Bay in 1959. *Haplosporidium nelsoni* is a natural parasite of *Crassostrea gigas* in Korea and Japan and was probably introduced to the East Coast of the U.S. through the introduction of *C. gigas* (Burreson et al. 2000). In the 1960s, this pathogen caused large-scale mortalities in both Delaware and Chesapeake Bays. While *H. nelsoni* has spread rapidly through natural populations since its introduction, the mechanism of transmission is unknown. An alternate or intermediate host has been hypothesized but not confirmed (Andrews, 1968; Haskin & Andrews, 1988). Incomplete knowledge about the life cycle and transmission of *H. nelsoni* should dictate a conservative management approach. *Haplosporidium nelsoni* is less tolerant of low salinity conditions than *P. marinus*, and requires salinity above about 12-13 ppt to cause significant oyster mortality. *Haplosporidium nelsoni* infections are eliminated by exposure to low salinity (<10-12 ppt) sustained over several weeks.

Impacts of Disease

The impacts of disease on oyster populations are related to salinity. In low salinity areas (<12 ppt), a proportion of the individuals that survive to adulthood (i.e., reproductive maturity = about 1 ½ inches) reach or exceed market size (3"and larger). However, these low-salinity areas also have low population recruitment rates because salinity affects the production of gametes, larval growth and settlement (Ford & Tripp1996). Oysters in low-salinity areas are also subject to mortality during freshets. In mid-salinity areas (12-14 ppt), oyster survival and growth are variable depending on climatic fluctuations – in wet years survival is generally higher but spat settlement and growth are poor, and in dry years the opposite is true. Higher salinity areas (>14 ppt) tend to have large numbers of small oysters because population recruitment rates are higher but fewer individuals survive to large size. This general pattern is further modified in portions of Maryland, Virginia and the upper Potomac by periodic, often lethal, freshets that occur in the lower salinity reaches of the upper tidal tributaries.

Burreson and Ragone Calvo (1996) defined critical salinity regimes based on *P. marinus* activity in Chesapeake Bay. Their definition of salinity zones differs from the salinity zones defined in this plan because they only take into account the activity of one of the diseases, but are complementary to each other.

1) If summer and fall salinities are consistently <9ppt, *P. marinus* infection is limited to light intensity and oyster mortality is low.
2) If summer and fall salinities vary from 9- 15ppt some infections may progress to moderate or heavy intensity and mortality may increase.
3) If summer and fall salinities are consistently >15ppt, moderate to heavy infections are more numerous and oyster mortality is relatively high.

Although an annual cycle of disease-induced mortality can be discerned in the Chesapeake Bay, disease mortality is compounded in consecutive years because *P. marinus* can overwinter. Consequently, for any given year class, disease mortality can have significant cumulative effects over several years. There is currently no direct method to distinguish between the effects of each of the diseases but the relative effects of *P. marinus* and *H. nelsoni* can be inferred from population data, disease diagnostics, and salinity.

Adopting a management strategy based on salinity zones will help to emphasize the regional differences associated with disease and oyster life history parameters. However, there are other factors such as growth, oyster density, and transplanting of seed oysters that can affect population structure that do not follow the usual geographic trends associated with salinity (Jordan 1995). Salinity zones are not static, but change seasonally and inter-anually, therefore, management strategies have to been adaptive to reflect environmental parameters.

Disease Management

Maryland and Virginia must confront different problems concerning disease. Virginia is faced with constant disease pressure. Under these circumstances, VMRC does not move infected seed or only small quantities. Maryland’s situation is more variable and dependent on climatic influences. Maryland DNR has the option to reduce total mortality by moving natural seed away from high disease areas and managing harvest, but can’t reduce the prevalence of disease. However, under drought conditions, Maryland is more like Virginia and disease management options are very limited. The challenge of rebuilding the oyster population is increasing oyster survival. Oyster restoration is intricately associated with how to manage activities in the presence of disease. Cleaning bars of infected oysters prior to planting, limiting the distribution of infected seed, avoiding disease areas when planting stock, and using specific pathogen-free (SPF) seed are site-specific activities that have been successful on a small scale. These activities reduce pathogen density and increase survival and productivity. The challenge is to extend the site-specific effects to a baywide scale.

Guidelines for Disease Management

Strategies that address disease problems have been in place for several decades and have been reevaluated as environmental changes have occurred. Disease management should continue to:

1) Move infected stocks only under suitable criteria.
2) Enhance hatchery production.
3) Monitor the effects of disease and environmental parameters on the oyster stock.
4) Promote and utilize research on development of disease-resistance oysters.
5) Monitor for parasite abundance and distribution

In addition, the following specific actions will enhance management practices directed at reducing and minimizing the effects of disease.

Action 3.1

Conduct an analysis of how disease management might affect overall survival and productivity. Answer the following question: What management strategies will help increase the oyster biomass over a large scale and in the long-term?

Action 3.2

Utilize disease management actions in all aspects of restoration activities and harvest to minimize the possibility of spreading disease.

Action 3.3

Increase hatchery production to supplement natural recruitment and mitigate the prevalence of *P. marinus* (refer to Chapter VI Hatchery Production for details).

Action 3.4

Establish broodstock sanctuaries in heavily infected areas to possibly produce disease resistant seed (see Chapter IV Sanctuaries for more details).

Action 3.5

Develop an interlab certification program for oyster diseases. Utilize the molecular diagnostic protocols for certifying SPF oyster seed developed by the VIMS Shellfish Pathology Laboratory (the Office International des Epizooties (OIE) laboratory for diseases caused by *Perkinsus* spp. and *Haplosporidium* spp.).

Action 3.6

Continue the protocol for certifying and using specific pathogen-free (SPF) seed.
a) Establish standards and refine criteria
b) Use only SPF seed in sanctuaries located in Zone 1 (<12ppt)

Action 3.8
Modify the Maryland seed program to reduce and minimize disease impacts:

a) Establish criteria to limit and/or restrict seed movement to certain regions depending on environmental conditions and disease levels.
b) Avoid transplanting older year classes that have higher levels of disease than young spat.
c) Rotate and/or clean seed areas to produce seed supplies that have a single year-class (single year-classes will have lower disease levels than older, multi-year classes). Since geographic areas have become more limited, track the use of seed areas.
d) Allow old seed areas to lie fallow and/or be harvested to reduce the number of infected oysters on the site before using the site again as a seed area.
e) Utilize the disease results from the Fall Survey to decide in the Fall rather than in the Spring, where and when diseased seed will be moved, using the criteria developed under section (a) above.
f) Transplant wild seed as soon as possible after set to minimize disease levels. Implement this action based on disease analysis and risks associated with moving fragile, young spat.

Action 3.9
Prohibit the culling of oysters while underway (i.e. moving from one oyster bar to the next) to minimize the movement of infected oysters, especially adults.

Action 3.10
Modify the oyster surveys as necessary to obtain the best estimates of oyster population data.

a) Increase the frequency and spatial intensity of sampling for disease prevalence and intensity in Maryland and Virginia
b) Seek additional funding to meet the additional monitoring requirements.

Disease Resistance

From an evolutionary perspective, natural selection due to disease mortality would lead to a resistant stock of oysters. However, oyster life history parameters complicate the process of developing resistance to oyster parasites. Oysters mature and spawn after one year of growth and may survive more than one exposure to parasites (especially *P.marinus*). Oysters with relatively low resistance may contribute offspring to the Bay's oyster population before succumbing to the effects of disease. This may slow the development of resistance within a given population. Another factor that complicates the development of resistance is larval dispersion. Oyster larvae can be transported from lower salinity areas where disease (i.e., selective) pressure is low to areas with higher salinity and a higher incidence of disease. These larvae, when imported from lower salinity areas, possess little resistance to parasites and contribute very little to the development of resistance in higher salinity areas. The reverse situation may also occur. To date, little has been done to quantify these effects on localized populations.

Research efforts to artificially breed strains of native oyster with greater disease resistance have been underway for a number of years. Several strains of oysters possessing varying degrees of disease resistance are currently available for commercial aquaculture, restoration, and repletion projects. Research is currently in progress to understand what role selectively bred strains of oysters could contribute to restoration efforts on a large scale (e.g., tributary or greater scale). Whether these strains can effectively infuse local oyster populations with greater tolerance to parasites is unknown. Alternatively, the selectively bred strains could serve as a means of starting new populations of oysters in areas where local populations are depleted. Ideally, a strain (or several strains) of native oysters could be developed that possess enough resistance to parasites to allow oyster populations to develop an age structure that mirrors oyster populations unaffected by diseases. An aggressive research and monitoring program is needed to better understand the dynamics of using disease resistant strains of oysters.

IV. Oyster Sanctuaries

One of the strategies for rebuilding the oyster resource and increasing oyster biomass is to designate sanctuaries throughout the Bay. The creation of sanctuaries will also protect the complex biological interactions of oyster bar communities and transitory finfish populations. Shellfish harvest will be prohibited in sanctuaries and habitat will be improved will be improved to facilitate oyster growth and survival. By protecting oysters from harvest and rehabilitating habitat (e.g, bar cleaning; addition of cultch) there is the potential to increase oyster biomass, i.e., broodstock (spawning adults) and larval production. Environmental parameters such as salinity and temperature, and disease mortality will significantly affect the success of oyster sanctuaries and the ability to attain the ten-fold increase in oyster biomass. Sanctuaries in disease-endemic areas may have the added benefit of encouraging selection for disease tolerance by providing protection from harvest.

Strategy 4.1

A network of clearly marked oyster sanctuaries will be established throughout the Chesapeake Bay and its tributaries.

a) Sanctuaries will encompass at least 10% of the historically productive oyster grounds, allocated per tributary or Bay region.

b) Sanctuaries will contribute to an increase in oyster biomass (10 fold increase from the 1994 baseline estimate of oyster biomass) and may contribute to the development of disease-tolerant broodstocks over the long-term (century or more).

Establishing Sanctuaries

The task of “where to designate” sanctuaries is multidimensional and extends over a broad geographic area. Salinity patterns, disease prevalence and intensity, bottom type, historical productivity, stock abundance, currents, and water depth are all factors that affect oyster production. Resources that are necessary for restoration activities within sanctuaries are limited, especially cultch, disease-free seed, and funding. Selecting priority areas, effectively utilizing resources and coordinating restoration activities among the various oyster partners are primary considerations for successfully establishing oyster sanctuaries. In order to guide, focus, and coordinate the multiple partners that participate in oyster restoration, the following strategies and actions are necessary.

Habitat Restoration Strategy

- Facilitate the establishment of self-sustaining oyster populations
- Rehabilitate degraded habitat
- Return harvested oyster shell, use available shell wisely, and develop alternative substrates for habitat rehabilitation
- Remove or minimize controllable causes of habitat degradation.

Action 4.1.1

Decisions on where to locate sanctuaries will be guided by the Virginia Oyster Restoration Plan developed by VIMS and VMRC and Maryland's Priority Restoration Areas developed by MDNR and the Maryland Oyster Roundtable Steering Committee. The maps will be used as a preliminary tool to focus restoration activities.

Virginia Oyster Restoration Plan:

The Virginia Oyster Restoration Plan identifies optimum sites for restoration projects based on suitable bottom habitat. The Plan consists of a series of maps and text that describe historical and current data relevant to oyster distribution, and current and projected habitat options for all Virginia waters of the Bay. The maps are categorized by regions or in the case of large watersheds, as part of a series that comprise a single region. The maps provide details on substrate including delineation of public and leased oyster grounds, and bathymetry relevant to operating vessels and barges in restoration areas. They also identify past restoration projects and their designations. Accompanying each individual map is a commentary on seasonal salinity changes; effects of storm induced freshwater flows; and disease incursion from downstream higher salinity water. An example of a map from the Virginia Oyster Restoration plan including the plan index can be found at the website www.chesapeakebay.net/cop.htm:

Maryland Priority Restoration Areas:

The Maryland Priority Restoration Areas consist of eleven regions throughout Maryland waters of the Bay. These areas were delineated based on average total oyster mortality, disease prevalence, annual spat settlement patterns, and the potential to meet restoration objectives. A restoration target (in acres) based on available oyster bottom habitat is included on each map. In addition to the maps delineating restoration regions, there are maps that identify the legal boundaries of natural oyster grounds and the locations of past restoration efforts including sanctuaries and reserves. The sanctuary and reserve maps include the size and amount of seed oysters used in their creation. An example map of one Maryland Priority Restoration area can be found at the website: www.chesapeakebay.net/cop.htm. There will be a process to determine priorities within the eleven regions in Maryland. The process will be developed through the Maryland Oyster Scientific Committee.

Action 4.1.2

The following steps will be utilized for establishing oyster sanctuaries throughout the Chesapeake Bay:

a) Identify appropriate oyster bottom (see site suitability criteria Section 2, chapter I).
b) Establish quality habitat with suitable cultch material and deploy (plant) substrate as appropriate.
c) Prohibit shellfish harvest and enforce restrictions.
d) Maintain suitable bottom condition and oyster production in the face of sedimentation and disease
e) Monitor and evaluate success

Action 4.1.3
Develop and implement a standard operating procedure for recording or charting GPS coordinates for oyster sanctuaries in order to track restoration progress and simplify data.

Action 4.1.4
Evaluate the use of alternative cultch material because all restoration efforts are dependent on the availability of suitable habitat and traditional shell dredging cannot support the scale of the current sanctuary initiative.

Action 4.1.5
Increase hatchery production because current levels are too low to effectively stock sanctuaries for restoration (see Chapter VI. Hatchery and Aquaculture)

Strategy 4.2
Management actions within sanctuaries are primarily based on salinity zones and focus on three key factors: growth, reproduction and disease. It is important to note that the salinity maps (figures 1 & 2) depict long-term averages. The zonal approach to management provides general guidelines for selecting project objectives and anticipating project results in each area. However, since salinity patterns vary annually and zone boundaries shift, a close examination of current environmental parameters is essential.

Strategy 4.2A
Zone 1 (5ppt<12ppt) Increase biomass and enhance reef habitat
Enhance reef/bottom habitat to increase oyster biomass and promote the development of living oyster reefs with broad size/age class structure that support a diverse reef community. Zone 1 sanctuaries are expected to contribute significantly to the near-term objective of achieving a 10-fold increase in oyster biomass by 2010 because of good survival in this zone.

Action 4.2A.1
Identify priority areas within Zone 1 that would have the most success at reaching the defined project objectives.

Action 4.2A.2
Rehabilitate and maintain oyster bottom habitat to provide planting substrate for seed oysters and optimal conditions for larval settlement.

Action 4.2A.3
Plant hatchery produced, SPF seed over several years if necessary to establish an oyster population with a diverse age class structure.

Action 4.2A.4
Monitor areas to evaluate oyster population status and measure progress towards the 10-fold increase in biomass.

The following table considers different project objectives and site characteristics that should be considered when determining placement of a sanctuary in low salinity zones and should be considered as guidance.

Project Objectives	Site/Project Characteristics
Long-term Survival	Salinity ≤10 ppt Limit the placement of oysters on bottom which may contain residual diseased oyster population
High oyster density	Seed at high densities (≥1million spat/acre) Use non-infected seed
Sustained population recruitment	Salinity ≥12 ppt and history of local spat settlement OR Repeated stocking with wild or hatchery seed
Reef growth outpaces sedimentation rate	Low sedimentation rates

Maryland waters have the potential to significantly contribute to the increase in biomass because certain regions are less impacted by disease. The potential for establishing Zone 1 sanctuaries in Virginia is limited and restricted to the upper reaches of tributaries where disease pressure is minimal. During sustained drought years the low salinity regions are far upriver and suitable habitat does not exist. Increases in biomass could occur during “wet” years when disease pressure is reduced.

Strategy 4.2B
Zone 2 (12-14 ppt) Transitional Area

The boundaries of Zone 2 shift because of variations in rainfall and resulting salinity. Consequently, Zone 2 will exhibit fluctuations in spat settlement and disease mortality. These types of fluctuations make it difficult to plan a project and predict the outcome. Projects in this zone must utilize current environmental data during planning. In Virginia, areas for consideration under Zone 2 sanctuaries include Nomini Bay, Lower Machoadoc Creek, Glebe, Coan and Yeocomico Rivers.

Action 4.2B.1

Critically examine long-term environmental conditions and develop adaptive project objectives for sanctuaries in Zone 2.

Action 4.2B.2

In areas that have predominantly Zone 1 characteristics, utilize Zone 1 guidelines and in areas that have predominantly Zone 3 characteristics, utilize Zone 3 guidelines.

Strategy 4.2C
Zone 3 (>14 ppt) - Develop Disease Tolerance

Oyster populations have been under constant disease pressure for decades. It is possible, but not certain, that disease resistance could develop via a management approach in Zone 3. Increasing biomass will be more difficult in Zone 3 than in any other zone. In the near term, there are low expectations that Zone 3 areas will contribute significantly to the 10-fold biomass objective. The strategy in Zone 3 will be to promote the development of disease resistance where disease mortality is high.

a) Encourage the long-term development of disease-resistance via natural selection.
b) Use field exposure of oysters to naturally occurring disease as the best large-scale method to encourage the development of disease resistant broodstocks.
c) Develop disease-resistant oysters as a long-term project.
d) To the extent possible, add to biomass.

Action 4.2C.1
Reestablish and maintain bottom habitat for oyster spat settlement and growth of disease-resistant adults.

Action 4.2C.2
Monitor Zone 3 sanctuaries to determine the effects of disease mortality.

Action 4.2C.3
Utilize Zone 3 as an area to test laboratory strains of disease-resistant oysters

Action 4.2C.4
Limit the use of natural seed to sanctuaries in Zone 3. The use of natural seed in repletion areas is allowed as long as disease protocols are followed (Chapter III).

The following table considers different project objectives and site characteristics that should be considered when determining placement of a sanctuary in the high salinity Zone 3 and should be considered as guidance.

Project Objectives	Site/Project Characteristics
Strong disease-dependent selection	Salinity (≥15 ppt) High disease mortality
Reproduction and spat settlement	Salinity ≥10 ppt and history of reoccurring spat settlement
Large numbers of individuals with potential disease tolerance	Plant at high densities Use disease tolerant strains.
Local larval retention (ideal for test location)	Hydrography – retentive system

Strategy 4.3
The jurisdictions will establish oyster sanctuaries to promote maximum ecological value.

Action 4.3.1
Identify areas of special interest throughout the bay, especially areas that may retain larvae (maybe auto-recruiting), and protect them using the sanctuary status.

Disease Management in Sanctuaries

Strategy 4.4
Implement the actions described in chapter III to address disease problems. In addition, the jurisdictions will take further action to minimize the spread of disease.

Action 4.4.1
Utilize only SPF hatchery seed in sanctuaries designated for oyster biomass accumulation, Zone 1 and Zone 2

Action 4.4.2
Place hatchery seed on newly created sanctuary bottom and not on top of infected oyster populations in order to prevent rapid infection of the disease-free seed.

Action 4.4.3
Prohibit the movement of infected oysters from higher salinity waters onto newly or previously created sanctuaries in Zone 1.

Enforcement

Sanctuaries are closed to harvest in order to reduce harvest pressure, to protect reef habitat, and to promote ecological benefits. Since closures are part of the harvest management, enforcement problems are discussed in Chapter V. Managing Harvest, section - Enforcement of Harvest Regulations (p.x). Additional enforcement options can be found in Action 5.12.

Strategy 4.5
To facilitate the enforcement of closed areas, especially sanctuaries, the following actions will be implemented:

Action 4.5.1
Sanctuaries will be placed in geographically distinct areas with enough space to create a buffer zone between harvest and sanctuary areas to enable enforcement.

Action 4.5.2
Sanctuaries will be buoyed and marked.

Action 4.5.3
The public and judiciary will be notified about sanctuary areas through educational initiatives, public announcements and stakeholder meetings.

Action 4.5.4
New enforcement measures will be identified and implemented. Additional manpower will be recommended if necessary.

Action 4.5.5
A "sanctuary hotline" will be developed to report any violations.

Background
Habitat Loss and Degradation

Oyster reefs as they occurred historically no longer exist in Chesapeake Bay. Many of the areas called "oyster bars" are remnants or footprints of the historic reefs. The initial loss of oyster reefs is attributable to massive harvests of the late 1800s and early 1900s. The impacts of harvest during this time were threefold: 1) oyster populations were reduced by approximately 75% (Hargis and Haven, 1995); 2) substrate for oyster settlement was reduced; and 3) physical structure of reef habitat was altered.

Once the structure of the oyster reefs were compromised, they were more vulnerable to sedimentation. During the late 1800's and early 1900's, sedimentation rates doubled and possibly, quadrupled, when approximately 80% of the region's forests were cleared (Brush, 2001). Although reforestation efforts have been successful, it is unclear how modern sedimentation rates compare to those seen at the time of extensive clearing. Defining what constitutes a degraded habitat and quantifying the extent of the degradation is problematic (Smith et al, in publication). New techniques for surveying the bottom suggest that only 1-2% of Maryland's historic oyster grounds can be classified as clean or lightly covered with sediment (Smith, unpublished data). Sediment-free shell is one of the most important components of quality oyster habitat (MacKenzie 1983; Smith et al. 2001). Minimizing the effects of sedimentation in the context of continued disease pressure is a monumental challenge for oyster restoration projects.

Local sedimentation problems continue in some areas because an increasing amount of land in the Chesapeake Bay watershed is covered by impervious surfaces. Impervious surfaces allow rainfall, which would otherwise enter the ground water table, to be delivered directly to surface waters. The rapid delivery of freshwater runoff to tributaries (known as a "freshet") temporarily reduces salinity, often to levels lethal to oysters. For example, in the upper Potomac River a one-inch rainfall event today results in a freshet equivalent in severity to that of a two-inch rainfall event 30 years ago. Frequent and severe freshets have essentially eliminated hundreds of acres of historic oyster habitat from the upstream portions of many tidal tributaries in Virginia. A problem of equal importance to sedimentation in areas of high salinity is disease mortality.

Spatial Extent of Degradation

Charted oyster grounds in Chesapeake Bay once encompassed over 450,000 acres. The Yates Survey (1911) and the Maryland Bay Bottom Survey (1985) charted between 215,000 and 219,000 acres of historic oyster grounds in Maryland. The Baylor Survey (1894) charted 243,000 acres of historic oyster grounds in Virginia state waters (40,000 acres were

ESTIMATES OF OYSTER GROUNDS
(in acres)

Historic Oyster Grounds:	
Maryland	215,000
Virginia	243,000
Total	458,000
Historically Productive Oyster Grounds:	
Maryland	100,000
Virginia	100,000
Total	200,000

charted from the seaside area). Charted oyster reefs are interlaced with patches of mud and sand. It is estimated that there were approximately 200,000 acres of productive oyster habitat. Based on the results of recent bottom surveys in Maryland, approximately 54% of the Yates bars are covered by sand; 35% are covered by mud; and 10% covered with cultch ranging from poor to excellent condition (Smith, 2001). Based on Virginia's Restoration Plan, there are approximately 11,500 acres of potentially restorable oyster habitat in the Virginia portion of the Chesapeake Bay.

Limited Shell for Habitat Rehabilitation

Oyster shell, either new (shucked) or from buried deposits, is the predominant and preferred cultch for oyster habitat projects in both Maryland and Virginia. Improving degraded oyster habitat across large areas will require more shell than is available from traditional shell deposits. The dominant source of shells for oyster restoration since 1960 has been dredged shells from buried shell deposits in the upper Bay. In Maryland, there are two large deposits remaining in the upper Bay and more deposits exist in the upper Potomac River. Access to these areas will likely be limited or even prohibited because of environmental and other issues surrounding dredging. Virginia has identified several potential shell deposits in the James River system. Permits to dredge buried shell have been acquired for two sites. Enough shell is available in these two sites to allow a significant oyster restoration effort over the next ten years.

Another source of shell is the shell already present on an oyster bar. Most of this *in situ* shell is covered by sediment ranging from a thin layer of silt to thicker deposits of sand or mud, and could be extracted and recycled in place to rehabilitate local habitat. This process would require permits and involve environmental issues such as suspended sediment and impacts to the benthic community. Before degraded bottom habitat can be efficiently utilized, potential sites need to be located.

In the short term, alternative substrates should also be considered. Currently, the most feasible function of alternative substrates is to provide a base for constructed oyster bars, which reduces the amount of natural shell necessary to create an oyster bar. Alternate materials that replace the need for natural shell, and can be economically manufactured in large quantities have not yet been identified.

Currently, most productive oyster areas and suitable bottom substrate are within areas where the state has recently planted shell. Shell plantings that are subject to harvest, high rates of disease mortality, low recruitment, and sedimentation, have effective lifetimes that average 3-5 years. After that time, shell plantings in these areas would require maintenance to ensure their continued productivity. The challenge for oyster restoration is to place clean shells in areas that effectively catch oyster larvae or place hatchery seed in these areas to facilitate oyster colonization. Areas will be successful only if oyster growth outpaces mortality and sedimentation.

V. Managing Harvest

Fishery Management

By definition, fishery management is the act of managing harvest. In order to support the 10-fold increase in biomass, new strategies for the fishery are necessary. The main strategy for regulating harvest and enhancing harvest potential is to establish sanctuaries and special management areas throughout the Bay. By establishing areas that are protected from harvest, fishing mortality rates (F) in managed areas and the overall F for the population will decrease. If these measures don't provide the needed increases in biomass, it may be necessary to further regulate the fishery. Prior to such an approach, F will be evaluated in relationship to increasing biomass. This evaluation will involve scientists, managers, interest groups and the watermen. Currently, the methods for regulating harvest include controlling the size and amount of oysters harvested through daily bushel limits, size restrictions, gear restrictions, time limits, seasons, limited entry and area closures.

Management Strategies

- Evaluate F at a level that does not compromise progress toward restoration objectives.
- Increase the amount of market size oysters available to support and enhance the fishery.
- Enforce harvest prohibitions.

Fishing Mortality Rate (F)

Fishery management strategies traditionally include a definition for overfishing and biological reference points that describe fishing mortality targets and thresholds. The ideal situation is to estimate the amount of oysters that can be taken safely from the population while maintaining a sustainable population size and age structure. For the oyster resource, the term "population" can be used in two different ways. It can refer to the whole baywide population of oysters or it can refer to the population on discrete reefs or bars. The term "population" in this document refers to the baywide population of oysters. When referring to discrete reefs or bars, the term "bar-specific" populations will be used. A target level for F has not been determined for the Chesapeake Bay oyster fishery. Prior to the 1920s, fishing was the major factor in the reduction of the oyster population in the Chesapeake Bay. Unlike some other fisheries, oyster harvesting reduced or destroyed the structure of oyster reefs thus degrading habitat. With the historic effects of overfishing, there was a loss of settlement substrate and sedimentation buried and degraded many sites. Harvest from the Chesapeake Bay continued and was relatively stable from 1920 through 1960 in Virginia and through the early 1980s in Maryland. Beginning in the late 1980s, disease became a major cause of size selective mortality in adult oysters. In recent years, harvest pressure in Maryland has decreased with fewer watermen reporting landings and fewer harvest days. Under current conditions, the impacts of adjusting F on stock size need to be better understood. A major challenge is to determine if a reduction in F will allow the oyster population to rebuild to a more productive level, and, at the same time, determine what level of exploitation is appropriate and will not compromise restoration efforts. The effect of no harvest or F=0 on oyster population dynamics, should also be considered. Sanctuaries are areas where F=0. Their overall effect on the total population needs to be evaluated.

In order to establish the appropriate level of F, it is necessary to better understand the interactions between disease and harvest. By age 3 it is estimated that 80% or more of a year-class will die due to disease in high disease areas (>14 ppt, Zone 3). Reducing F on the surviving 20% could affect population size and reproduction but may only have short-term benefits. In lower disease mortality areas (Zones 1 & 2) where survival is higher, decreasing F may be more beneficial and lead to increases in biomass over time. Understanding the interaction between F and disease is crucial, especially how the interaction impacts achieving the tenfold increase in biomass. Important questions include:

1. Can adjusting F increase oyster standing stocks in the presence of disease? Are there areas where disease mortality plays a greater role than F?
2. What would be the effects of a harvest moratorium on increasing oyster biomass?
3. What are the genetic considerations of removing large and/or disease tolerant individuals? Is there evidence of disease tolerance in the Chesapeake Bay oyster population?

Action 5.1
Establish a network of oyster sanctuaries (refer to Chapter IV. for details) and special management areas throughout the Bay to limit harvest and increase oyster production

Action 5.2
Define appropriate biological reference points for the oyster resource based on the results of the bay wide stock assessment (tentative completion 2003), using the following steps:

- Determine the current level and spatial distribution of F.
- Evaluate whether adjusting F could significantly contribute to progress toward the tenfold increase in biomass.
- Determine the appropriate level of F.
- Incorporate the F into the Comprehensive Oyster Plan.
- Adopt harvest controls to attain the F.

Both the current F and a F that would contribute to the ten-fold objective are likely to vary among salinity regions. Establishing the process for determining F is the first step in developing targets and thresholds for the oyster population. There will be additional input from the scientific community, stakeholders and interest groups on the appropriate methods to implement harvest controls.

Action 5.3
Utilize the disease guidelines and actions presented in chapter III in all aspects of special management areas and the fishery.

Special Management Areas

Currently, there is a minimal public fishery in Virginia and the Maryland Repletion Program (see page 32 for more details) supports approximately 80% of the commercial oyster harvest (MDNR). Areas established by the Repletion Program are open for harvest as specified in current laws and regulations. Harvest will be enhanced by a relatively new initiative, i.e., establishing open and closed areas throughout the Bay. Harvest will be allowed from these areas on a rotational basis. This strategy will delay harvest beyond the current minimum size of 3". The rationale for this approach is that larger oysters (> 4") have greater meat yield and market value; and, are expected to contribute more to population biomass, reproductive potential and ecological functions.

Harvest Reserves (Maryland)

To date, Maryland has designated 19 areas as harvest reserves in Zone 2. The most recently designated reserves were selected based on "good" bottom and low-to-moderate disease mortality. Since the best grow-out sites can change from year-to-year, designating new harvest reserves will be based on the best available information. Specific criteria concerning the management of harvest reserves have been drafted and regulations are being developed. The draft guidelines are to delay harvest beyond 3" until 50% of the population in a reserve has reached 4". The area would be opened on Saturdays (the regular commercial fishery is closed on Saturdays). Harvest would be limited to maintain broodstock in the reserve. Harvest would be allowed during peak market demand to obtain the highest economic value for the larger oysters. To date, none of the nineteen reserves in Maryland have been opened for harvest. Maryland DNR has authority to regulate harvest within the allowed open season but new regulations would be required to harvest oysters outside the season. There is a limited amount of resources, i.e., hatchery seed , shell, and funding, to support the establishment of harvest reserves. The same resources are needed to establish sanctuaries. While it has been informally understood that new funding would be allocated on an equal basis between sanctuaries and harvest areas (including special management areas), it will be necessary to formally decide how to allocate all the limited resources between sanctuaries and harvest reserves.

Open and Closed Areas (Virginia)

Most of Virginia's oyster bars were closed in 1994. Since then, oyster harvest has been managed on a bar-specific basis. Areas are closed for at least three years to allow oysters to grow undisturbed and then opened to support a modest fishery. Virginia has a standing stock criterion, which can be used to close an area to harvest. The commissioner of the marine resources can close an area to harvest when the standing stock of oysters is depleted by 50% or more. The initial estimate of standing stock for each area is determined by the oyster replenishment officer and is the volume of oysters as of October 1st of each year. The procedure for opening areas is as follows. The replenishment officer requests areas to be opened at the monthly Virginia commission meeting. A 30-day comment period begins at the time of the request and interested parties have the opportunity to comment in writing or by attending the next commission meeting. After the 30-day comment period, the nine Virginia commissioners decide if the area under consideration should be opened or modified based on the comments they have received.

Action 5.4
Develop guidelines for managing fishing effort and monitoring oysters in open and closed areas:

1) Determine the criteria for opening and closing areas. Criteria may vary depending on regional differences or new management objectives. Some options on when to open areas to harvest, and how to regulate fishing effort include:

a) When 50% of the bar-specific population is larger than 4"
b) For a limited time period such as
1) one week at a time
2) special times when market demands are highest, i.e., prior to Thanksgiving or Christmas

c) Under a particular disease scenario, i.e., if high disease mortality is eminent, allow harvest before natural mortality occurs
d) Under a predetermined harvest limit or total allowable catch (TAC) based on abundance estimates and/or population size/age structure

2) Monitor the population size, age structure, and disease prevalence and intensity on a particular bar or in a particular area.

3) Determine level of acceptable exploitation

a) Determine harvest rate depending on oyster size and abundance.

b) Establish a decision-making protocol for harvesting under different disease conditions and at different size limits

4) Regulate harvest and gear type

a) Limit participation

b) Establish daily limits

c) Utilize time and season limits.

d) Limit and/or reduce fishing impacts due to harvest gear that can impact shellfish habitat and benthic populations.

5) Develop additional monitoring efforts depending on criteria for opening/closing an area

6) Close area when harvest criteria are met.

Action 5.5
Utilize the site selection criteria set forth in this plan to select special management areas (see Section 2, chapter I for details).

Action 5.6
a) Maryland DNR will utilize the ORTSAC to review and make recommendations on where to locate harvest reserve areas, and MDNR, MWA, and ORP will be responsible for implementing the recommendations.
b) Virginia will utilize their current system to review and make recommendations on open and closed areas.

Action 5.7
Identify and implement regulatory and legislative changes needed for managing open and closed harvest areas.

Action 5.8
a) Evaluate how rotating open and closed areas contributes to reproduction, oyster biomass, and harvest.
b) Based on the evaluation, adjust harvest controls if oyster biomass is not increasing.

Repletion Program
The Maryland Repletion Program is the major source of harvestable oysters because of the impacts of disease in the entire Chesapeake Bay. The Maryland Repletion Program has focused on increasing the size of the oyster harvest by planting shell and transplanting seed oysters. Oyster shell is planted in areas with high natural spat settlement, usually in waters of the mid- to lower Eastern Shore and the lower bay. Seed oysters are transported to oyster bars in grow-out regions where survival rates are higher than their original location. Currently, the Maryland Repletion Program plants over 2 million bushels of shell and between 150,000 and 500,000 bushels of seed depending on spat settlement levels. The amount of shell and seed varies from year to year depending on availability. A new limitation may be the supply of shell from upper Bay shell deposits. Acquiring new permits is difficult and may end the dredged shell program, which is the “backbone” of the Maryland Repletion Program and the fishery.

The Virginia Repletion Program is similar to Maryland’s program except it focuses on moving shell. It no longer has an active seed component because of disease. Since the 1990s, the movement of seed has been curtailed. Virginia depends on the availability of dredged shell and shucked shell to continue their program.

The repletion programs track the exact coordinates, depth, bottom type, salinity, bushels planted, number of seed planted, acres planted, and survival rates for each planting. Through the repletion programs’ efforts, oyster habitat, recruitment, growth and survival are potentially enhanced. To date, none of the aspect of the repletion program has been evaluated in terms of baywide oyster population dynamics. Evidence suggests that in the past, when the programs moved seed infected with *Perkinsus* to lower salinity areas, pathogens may have spread and possibly extended their range. The scope of this problem has decreased with increased awareness and new disease management strategies. The repletion programs are limited by natural reproduction (spat settlement), disease infection, and funding. Disease has been the greatest limitation over the past 15 years.

Disease mortality has severely compromised planted areas (shell and seed), reducing bar-specific populations and harvest to record low levels.

Annual Workplan

The repletion programs develop an annual work plan in the following manner. The Maryland Fall Dredge Survey provides data on spat settlement, disease, and mortality. Maryland DNR Shellfish Division staff use data from the annual survey in combination with data on bottom type, site surveys, salinity, harvest trends, and legal mandates to draft a work plan at the beginning of each calendar year. In general, seed planting areas are selected to maximize survival to market size and shell planting areas are selected to capture natural spat settlement. The draft work plan is further developed with the county oyster committees, where specific bars are listed for planting. The work plan follows the guidelines established by the Maryland Oyster Roundtable Action Plan, and is reviewed by the Oyster Roundtable Steering Committee. The work plan estimates the amount of seed and shell available and describes the planting sites that have been selected. The Steering Committee provides comments on the work plan and appropriate changes are made if needed.

The Virginia Repletion Program follows a similar process. A work plan is developed and describes where the placement of shell will occur. Appropriate data collected through the Virginia Fall survey, is used to determine the appropriate areas. The draft work plan is presented to the Virginia Commission for adoption. The Commission adopts the work plan as a guideline for the following year's work.

Action 5.9

1) Follow project guidance criteria specified in section xx when developing repletion program work plans.
2) Maintain the Maryland workplan review process as follows:
   a) DNR drafts the annual workplan
   b) Workplan is reviewed by county oyster committees
   c) Detailed list of planting sites are added to the workplan based on county recommendations and included for consideration.
   d) Revised workplan is reviewed by the Oyster Roundtable Steering Committee
   e) Additional changes are made to the Annual Workplan if necessary

Action 5.10

Maryland will evaluate the effects of the repletion program on oyster population dynamics and oyster habitat, and document how it contributes to an increase in oyster biomass and habitat.

Controlling Fishing Effort

Management strategies for the Maryland oyster fishery are considered by a number of advisory groups working with MDNR. The Maryland Oyster Roundtable Scientific Advisory Committee (ORTSAC) will be charged with determining appropriate biological reference points for the oyster resource. Depending on the biological reference points adopted through the ORTSAC and discussed through the public review process, additional controls on fishing effort and regulatory changes may be necessary. If Virginia's situation improves, the committee that reviews and develops management strategies for the fishery should be expanded to include Virginia representatives.

Action 5.11
Control oyster harvest through one or more of the following methods to reach an appropriate fishing mortality rate (F) determined by the oyster scientific committee.

1. limited entry into the fishery (expand on current policies)
2. time limits
3. altering size limits, either >3" or adopting a slot limit or both gear restrictions
4. bushel limits
5. seasonal restrictions on public grounds (Oct-Mar)
6. area restrictions (eg. sanctuaries and reserves)
7. partial or a full moratorium with or without a license "buy-out."
8. establish a total allowable catch (TAC) based on current environmental conditions (This action may require compensation to harvesters. If a conservative F and TAC are implemented, there would be losses to the fishery until the stocks could rebuild. This may be less expensive than other restoration approaches.

Alternate methods for controlling harvest and/or effort can be considered through the committee and public discussion. Methods for regulating harvest are not limited to those listed. Strategies for controlling fishing mortality will require input from the stakeholders and possibly changes in regulations.

Enforcement of Harvest Regulations

Sanctuaries and special management areas represent significant investments of money, shell, and seed for rebuilding oyster biomass. Effective enforcement of closed areas is crucial for protecting oyster habitat and ecological functions, for protecting scientific investigations underway in these areas, and to protect the potential increases in biomass. Funding for additional restoration projects depends on adequate enforcement levels. Since oyster sanctuaries will be closed to harvest and other areas will be alternately opened and closed to harvest, there are concerns about poaching. As the number of protected areas increase, the task of protecting the array of sites will become increasingly more difficult. To facilitate enforcement, all special management areas are marked with permanent buoys. Maryland has increased the fines for poaching and an educational outreach effort is underway.

Virginia generally builds sanctuary reefs that are 3-dimensional and are different from the surrounding 2-dimensional harvest areas. With this configuration, sanctuary reefs are interspersed within harvest areas. All areas are marked and harvest is prohibited from the sanctuary reef areas. The 3-dimensional nature of the sanctuary reefs act as a natural deterrent to harvest. Watermen and the public have accepted the reef concept, and poaching has not been a significant problem. If conditions change, additional law enforcement measures will be adopted.

Action 5.12:
Strengthen the enforcement of oyster closures in sanctuaries and special management areas. Some potential enforcement options include:

1) Increase enforcement staff (marine patrols).
2) Make penalties more severe
3) Increase fines
4) Add points to license system for violations
5) Buoy all sites
6) Place physical deterrents in sanctuaries (e.g., boulders)
7) Use innovative techniques to identify oysters from sanctuaries (e.g., foreign cultch materials, wire tagging)
8) Use educational and outreach efforts with the general public/landowners/court system/watermen
9) Implement a citizen hotline for reporting violations

Status of the Oyster Fishery

The Maryland oyster harvest has declined significantly since the 1800s. After a peak harvest of 15 million bushels in 1884, harvest decreased to approximately 3 to 4 million bushels (1900s) as a result of overfishing. From 1925 through the 1982 season, the commercial fishery harvested between 2 and 3 million bushels per year. By the late 1980s, the commercial harvest decreased to approximately 400,000 bushels and reached a record low of 80,000 bushels (1994). Over the last decade, the average annual harvest has been 233,000 bushels with the most recent harvest at 148,000 bushels (2002). From 1987 onwards, the decrease in harvest was primarily due to the geographic spread of disease, continued harvesting, habitat degradation and their combined effects on total mortality. Before disease became a dominant factor in the 1980s, the oyster population in the Maryland portion of the Chesapeake Bay supported approximately a 2.0 million bushel commercial fishery for over 60 years.

The Virginia oyster harvest at the turn of the century was approximately 6 to 7 million bushels. Similar to Maryland, Virginia landings in the early 1900s, dramatically declined due to overfishing. By the late 1920's, oyster landings were approximately 2 million bushels. Landings increased and stabilized between 3 and 4 million bushels from the 1930's through the 1960's, and were supported through increased output from private leased ground. Following outbreaks of MSX in the early 1960's, Virginia's harvest decreased to less than 20,000 bushels by the mid 1990's and have remained at that level ever since. Commercial harvest from the Virginia public fishery was 16,000 bushels (2001/2002 season). The primary gear type for harvesting oysters in Virginia was hand tongs. Historically, Virginia's production was primarily from privately leased oyster grounds, but the severe impact of disease curtailed economic investment by private industry. Prior to disease, the commercial harvest was supported through the public grounds from October through March, and harvests from private grounds supported the commercial market during the other months. Public market production was derived from both public seed movement and natural spat settlement. Private market production derived mostly from seed oysters that were harvested from public oyster seed beds and moved to private grounds. All efforts to move seed oysters from public seed beds or private seed beds are currently economically unsuccessful in Virginia. (see Figure 3)

Estimates of annual exploitation in Maryland have ranged from 21% to 72% (1985-2000) of market-size oysters (MDNR). The estimate of population size in Maryland is approximately 0.6 billion oysters. During 2001, the Maryland commercial fishery harvested 348,000 bushels (between 122 million and 140 million oysters based on 350-400 oysters/bushel). Since there is a minimal commercial harvest from Virginia, only the Maryland fishery will be described in more detail.

The major harvest areas in Maryland during the 2002 harvest season were Eastern Bay (23%), the upper Bay (13%), and Broad Creek (Choptank River) (3%). Major harvest areas change from year to year but Eastern Bay, the Chester River, the upper Bay and the Little Choptank have been major harvest areas in the last few years. Most harvest areas are dependent on the Maryland repletion program activities to augment and enhance population size. The repletion program is implemented through seed planting which directly stocks small oysters in designated areas and through shell planting which benefit the stock as a result of natural spat settlement on shell. The predominant gear type for harvesting oysters in Maryland is hand tongs. During the 2001/02 season, hand tongs harvested approximately 41% of the total landings. Over the past twelve years, hand tongs have harvested between 38% and 75% of the catch. Patent tongs and divers harvest approximately 20% each and power dredges and skipjacks the remaining percentage. Each gear type has a varying rate of efficiency in capturing oysters and none are 100% efficient. In Maryland there is a 15 bushel daily limit on harvest. However, the reported average bushels per man per day have not been limited by the daily bushel limit since the 1970s. There are individual harvesters who are limited by the 15 bushel daily limit, but the limitation usually occurs early in the season. As the season progresses, catch falls below the daily limit. The dominant factor in declining daily catch can be attributed to declining oyster populations with increasing disease mortality. During the 2001/02 Maryland season, the average number of bushels harvested per day was 6.8. During the 1990s, the dockside value of oysters has varied between $16 and $27 per bushel. Compared to the 1970s, the price per bushel has doubled and in some instances, tripled. (see Figures 4 and 5)

The number of license holders in Maryland that report harvesting oysters has decreased from 2,800 in the mid-1970s to approximately 915. The lowest number of harvesters occurred in 1994 when only 760 reported. During 2002, over half of the license holders caught less than 50 bushels per season and one third reported catching over 100 bushels.

VI: Hatchery and Aquaculture Considerations

Oysters have been cultured or artificially propagated since early Roman times and modern oyster farming can be traced back to the 1600s in Japan (Castagna et al. 1996). In the Chesapeake Bay, state agencies and private planters, have practiced oyster culture in a variety of ways for more than a century. Traditional methods involved the placement of oyster shell in areas of high larval settlement and subsequent transplanting of newly settled spat for grow-out in areas favoring oyster growth to market size. Most recently, hatcheries have been used to artificially produce seed oysters for a variety of purposes, ranging from recreational and commercial oyster aquaculture to broodstock enhancement and support of commercial fisheries. Private aquaculture was once productive in Maryland and Virginia (in VA a major fishery) until disease became virulent. Although there are numerous constraints on aquaculture practices, the impact of disease is currently the major impediment.

Oyster hatcheries can produce seed oysters with potentially improved quality. Hatchery seed can be free of endemic oyster parasites that may provide some advantage when placed in the natural environment. In areas of low natural spat settlement, the use of hatchery seed provides an initial, dense population of oysters that otherwise would not be available. Hatchery production can also be used to artificially select for genetic traits which may lead to increased survival (eg., tolerance to MSX and/or Dermo). Currently, demands for hatchery seed exceeds production.

The magnitude of spat settlement and early survival varies both spatially and temporally. Comparisons of historic and current spat settlement data indicate that the overall magnitude of spat settlement has decreased over the past century (Meritt 1977; Krantz 1995). Using hatchery-produced oysters to enhance broodstock could be a critical component in augmenting larval production and recruitment when natural spat settlement is low and could play a key role in rejuvenating oyster populations. However, the overall number of oysters that hatcheries can generate on an annual basis cannot compare with the numbers of larvae produced baywide by wild stocks in most years. To date, hatchery produced seed has been utilized for a variety of projects, including stock enhancement on sanctuaries, public oyster bars, community restoration sites, oyster gardening and commercial aquaculture.

Hatchery Production

Maryland

Oyster hatcheries have been in operation in Maryland since the 1960s. At least six privately funded hatcheries have been operated over varying lengths of time with only limited success. None of the hatchery endeavors appear to have been economically profitable. In the past when wild oyster seed was abundant from locations like the James River, the use of hatcheries for seed production wasn’t widely utilized or economically favorable. More recently, as disease distribution and intensity has increased, oyster farming has become a larger economic risk for individual investments.

Currently, there are no private hatcheries located in Maryland to provide seed oysters for either restoration or private aquaculture. There are, however, three state-owned facilities that culture oysters: Horn Point (University of Maryland's Center for Environmental Science); Deal Island, and Piney Point (both run by the Maryland Department of Natural Resources). The primary role of these facilities is to provide spat on shell to augment restoration efforts. Designated uses include seed for sanctuaries, harvest reserves, public oyster bars, and privately managed restoration sites. A percentage of the seed is utilized for oyster gardening by private citizens for placement on sanctuaries sponsored by the Chesapeake Bay Foundation. In addition, the Horn Point hatchery is used extensively as a teaching tool. Spat are used in research and demonstration projects designed to improve restoration techniques and knowledge. Horn Point has a significant outreach program with private oyster growers, public watermen and others. The University of Maryland and the Sea Grant Program support these activities.

Horn Point hatchery has an annual production capacity of approximately 100 million spat on shell. With the completion of an expanded facility in 2003, production is expected to more than double the annual capacity to between 200 and 400 million spat on shell. Piney Point and Deal Island have a combined production potential of 100 million spat on shell, but low levels of funding and low availability of larvae have kept production below 10 million (MDNR). While the level of oyster seed production is expected to fluctuate from year to year, a stabilized source of funding would help to ensure a more steady supply of oysters for the purposes identified in this plan.

Hatcheries could be an important component for restoring oyster stocks in Maryland, given the current condition of low natural recruitment. It is unknown if stocking hatchery oysters as broodstock will increase recruitment but additional hatchery capacity would be required in order to try to meet the tenfold increase. The demand for hatchery produced seed for use by multiple user groups exceeds the current supply. Increasing hatchery production would help meet the needs of restoration groups as well as the private aquaculture industry.

Action 6.1:

Maryland will increase hatchery production of specific pathogen free (SPF) seed by 100% to support the 10-fold increase in oyster production.

a) Increase and maintain as necessary, the operating funds for each Maryland facility.

b) Evaluate and optimize the efficiency of each facility in order to ensure maximum production of spat.

Action 6.2.
The Army Corps of Engineers (COE) will conduct an analysis of hatchery project production in relationship to environmental benefits as part of its long-term restoration planning, and determine if augmenting or building new hatchery (ies) is warranted.

Virginia

Virginia has many private commercial hatcheries but most of them concentrate on clam seed. The primary role of the commercial hatcheries is to provide cultchless seed to commercial growers, non-profit organizations, and individuals in support of commercial aquaculture, oyster reef restoration and oyster gardening. One of the hatcheries currently produces approximately 10-12 million cultchless spat and is not at full production capacity. Another commercial facility is primarily a clam aquaculture facility with oyster production as a secondary program. It currently produces 5 to 10 million cultchless spat. In addition to the commercial hatcheries, a shellfish research hatchery is located at the Virginia Institute of Marine Science (VIMS). The VIMS hatchery is the leading shellfish breeding station in the Chesapeake Bay area and conducts research on shellfish genetics, such as the development of disease resistant strains of native oysters.

The uses of Virginia hatchery production are similar to Maryland. Virginia hatchery-produced seed is used by commercial aquaculturists; by oyster gardeners for both private consumption and for oyster restoration (e.g.,in support of Chesapeake Bay Foundation efforts to place mature oysters on sanctuary reefs);. Primarily, the hatcheries produce spat from selectively bred strains of oysters produced in a controlled breeding program. The use of hatchery-produced seed for restoration is just getting started and will soon be used for oyster restoration programs by ACOE and VMRC. Although the commercial hatcheries are currently not producing to capacity, this situation may soon change with the demand for large quantities of seed for restoration. More private hatcheries may enter the market if there is an increased demand for seed, cultched or cultchless. Given the high disease intensities in the lower part of the Bay, disease resistant strains will be used almost exclusively. Quality control and genetic considerations will be important aspects of hatchery production.

Action 6.3
Virginia will increase hatchery production of disease resistant seed by XX% to support the 10-fold increase in oyster production.

a) Increase and maintain as necessary, the operating funds for oyster breeding in Virginia.

b) Evaluate the feasibility of a public or public-private hatchery for the Commonwealth.

Action 6.4
The COE will conduct an analysis of hatchery production in relationship to environmental benefits, and determine if augmenting or building new hatchery (ies) is warranted.

Action 6.5
Virginia will develop strategies for effective seeding of reefs and their effects on recruitment, especially in relation to the spread of disease resistance in the wild population.

Future use of hatchery seed by commercial aquaculturists is contingent on emerging technologies in aquaculture and the survivability of disease resistant oyster seed. Hatcheries are currently underutilized for commercial oyster culture but may gain prominence if significant gains are made in disease resistance. The use of hatchery seed may be the only way to circumvent the high disease pressures in the lower Bay.

Genetic Concerns of Hatchery Production

There is widespread recognition that conservation of genetic diversity in exploited resources and populations under restoration can ensure the greatest level of overall fitness within those populations. The genetic diversity of oyster populations in the Bay is currently unknown, but has likely been altered by a variety of activities over the past century or more, including the movement of oysters between sites in the Chesapeake Bay and the transplanting of oysters into the Chesapeake Bay from other coastal areas. The use of hatchery-produced oysters for restoration, repletion or commercial aquaculture also has the potential to affect genetic diversity, though the exact magnitude of these effects is unknown.

Recognizing the need to maintain genetic diversity while still ensuring high levels of production for commercial and restoration purposes, hatchery operators have begun to implement protocols designed to minimize undesirable genetic effects of hatchery produced oysters on remnant oyster populations. Some practices now being employed include careful tracking of hatchery stocks used for restoration projects, maximizing the number of broodstock oysters used in a given spawn, co-mingling larvae from different spawns of the same strain, and using a variety of different stocks over time to maximize variation within a given transplanting site. Additional research is needed to better characterize the “natural” genetic variation within oyster populations and to define the effective population size for oyster populations throughout the bay. As new information becomes available, the development of more formal protocols may be necessary to help maximize genetic diversity while increasing the overall fitness of the Bay’s oyster population in the face of MSX and Dermo.

Action 6.6
Continue to track the broodstocks used in hatcheries for restoration or replenishment activities.

Disease resistant/tolerant oysters and their role in restoration

The use of selectively-bred, disease resistant strains in oyster restoration efforts is less extensive in Maryland and more widespread in Virginia. Using selected strains of oysters in the wild has the potential to improve survival and may result in increased production. Large-scale experiments using genetically enhanced oysters are just beginning and may be limited because of financial restraints. A consortium consisting of Rutgers University, Virginia Institute of Marine Science, University of Maryland, and University of Delaware has developed various strains of oysters, such as DEBY and CROSBreed, that are less susceptible to oyster pathogens. More disease resistant strains have been developed at the VIMS hatchery and were originally bred for aquaculture. The best use of disease resistant strains has not been defined. Efforts to use selectively bred oyster strains to infuse more desirable traits into the wild population are just getting underway and on-going research should help to define how these stains are used. There is a research project underway to observe gene flow from restored reefs stocked with disease resistant oysters to surrounding areas of recruitment (S. Allen pers. comm.). Documenting the spread of disease resistant genes among wild oysters is the ultimate aim of the research.

Virginia will begin a new strategy to construct three-dimensional reefs and seed them at high densities with large, disease resistant strains of oysters (CROSBreed, DEBY, etc). Construction will take place in “trap” estuaries (small tributaries where larvae have a better chance of being retained in the same system). Reefs will also be built in high disease areas to field test various strains of disease resistant stocks and assess their effectiveness in the wild.

Action 6.7

Develop recommendations for using disease resistant strains of native oysters for restoration in the Chesapeake Bay. Selectively bred oyster strains should be used for restoration only in areas where native oysters are locally depleted (Allen & Hilbish 2000)

Action 6.8

Assess and evaluate the use of disease resistant stocks as a tool for increasing disease resistance in the native oyster population in the Bay.

Action 6.9

Monitor restoration activities to clarify the interaction between selectively bred strains and wild stocks of oysters.

Aquaculture

Historic and current perspective of aquaculture

Production of oysters by private-sector aquaculture has the potential to contribute to the overall increase in oyster biomass, ecological value and economic benefits to the Bay. To date, the Bay's oyster aquaculture industry has involved two approaches: leased bottom aquaculture and off-bottom aquaculture.

Leased Bottom Aquaculture

The cultivation of oysters on leased bottom has a long history in Chesapeake Bay. Leases issued by the states give leaseholders exclusive rights to cultivate, hold, and harvest oysters in specific areas. In Maryland, total acreage under leased bottom peaked in 1990 at approximately 10,000 acres and has decreased since then to approximately 7,500 acres. Approximately 800 leases, controlled by about 300 individuals are responsible for the leased ground acreage. Based on reported data, production from leased bottom in Maryland has averaged about 2% of the total harvest (Jordan et al. 2002). In Virginia, approximately 100,000 acres are available for leased bottom production through about 3,000 leases. Before pathogens arrived in Chesapeake Bay, oyster production on leased bottom exceeded the Virginia's public fishery. Current production has been reduced to approximately 20,000 bushels (Jordan et al. 2002).

Off-Bottom Aquaculture

Large scale off-bottom aquaculture is minimally developed in the Bay. In Maryland, there are 26 experimental aquaculture permits for oysters in use. Estimated oyster production from experimental culture was approximately 120,000 oysters during 2001. One of the most developed off-bottom aquaculture approaches in the Bay is oyster gardening. It involves the cultivation of oysters by citizens, usually in floats tied to private docks, and is practiced in both Maryland and Virginia. Oyster gardeners have several different objectives for their activities, including personal consumption, improving local water quality, and providing oysters for restoration activities.

Constraints on Further Growth of the Aquaculture Industry

The availability of a consistent supply of disease-resistant seed oysters is a significant constraint on the growth of the industry. Collection of natural seed by commercial oyster producers is not cost-effective at the present time due to the inconsistency of spat set in any one area. In a ‘chicken-and-egg’ dilemma, capital investments necessary for growth in the industry are not likely until more seed is available, and investments in seed production are not likely until cost effective market production from the seed is demonstrated.

Prior to 1999, there was no commercial off bottom aquaculture in Maryland. Although approximately 95% of Maryland’s waters are classified as approved for shellfish harvesting by the Maryland Department of the Environment (MDE), the sites chosen by off bottom aquaculturists and permitted by MDNR, are in shallow areas where tidal flushing is minimal and where there is the potential for polluted runoff. Often these areas are denied permits because of water quality and unsafe conditions for harvesting oysters for human consumption. The biggest impediment to aquaculture is disease and is a major deterrent for active and/or new leasing activity. Leasing of Bay bottom by corporate entities is prohibited by the state, thereby, excluding many large investments in bottom culture. For the small operator, extensive state and federal permit requirements may inhibit efforts to develop off-bottom aquaculture. In Maryland there is a need for new regulations specific to aquaculture activities and new resources for regulatory oversight. Both Maryland and Virginia have an active and well-coordinated outreach program to stimulate private production of shellfish. These programs have been active for decades and network with national and international networks. Finally, the challenge of managing around disease is a significant constraint on the development of the aquaculture industry. At this time, there is little interest in using hatchery-produced native oysters because of increased operating costs associated with intensive aquaculture.

Recommendations for Supporting the Growth of the Aquaculture Industry

Consistent with the overall objective to achieve a ten-fold increase in native oysters in the Bay by 2010, an interim objective to achieve an increase in native oyster production by the aquaculture industry should also be considered. One advantage of this approach is the investment of private funds versus government funds. Achievement of this objective will be supported by the following actions:

1. Increase the availability of disease-resistant or specific pathogen-free native seed oysters. This initiative is addressed above in the section on hatcheries.

2. Create aquaculture policies that protect the environment and are responsive to the needs of the industry. This could include a time-sensitive permitting process, simplifying permit conditions, and removing or modifying restrictions on corporate participation.
    - In Virginia, reevaluate the recommendations brought forth in 1996 in “An Analysis of Organic Statutes and Regulations which Inhibit Shellfish Aquaculture Operations” and fulfill the remaining recommendations if appropriate.

- In Maryland, utilize the recommendations of the 2002-2003 Task Force on Aquaculture to improve development. Promulgate new regulations and provide resources for regulatory oversight. Clarify a procedure to assure consistency with National Shellfish Sanitation Program requirements, fisheries and wetland laws.

3. Continue to provide education and training to lease-holders and other aquaculture operators through the Sea Grant Program.

4. Develop and distribute a positive public communication message concerning the benefits of native oyster aquaculture to the Bay (e.g., biofiltration, living resources habitat, water quality and public health issues).

Implications for using Non-native oysters in Aquaculture

The practice of using exotic or non-native oysters for successful aquaculture production occurs throughout the world. With the decline of native oyster production in recent decades, the use of non-native oysters has been considered in Chesapeake Bay as a mechanism to rehabilitate the oyster industry. Two species of oysters currently used worldwide for aquaculture and native to Asia, have been studied for potential introduction into Bay waters; *Crassostrea gigas* and *Crassostrea ariakensis.* Early studies of triploid (sterile) *C. gigas* by the Virginia Institute of Marine Science (VIMS) and Maryland DNR indicated that it was a poor candidate for successful use in the Chesapeake Bay. Studies shifted to triploid *C. ariakensis*. Initial field trials indicate that it grows fast and tolerates the two known oyster pathogens *H. nelsoni* and *P. marinus* better than the native oyster (Calvo et. al. 2001). It also tolerates the warm and silty Bay environment better than *C. gigas*.The findings and field trials suggest that using triploid *C. ariakensis* in commercial aquaculture endeavors is a viable option for rebuilding the oyster industry. However, there are potential risks and considerable uncertainty when introducing an exotic species to an ecosystem.

In 2001, a symposium was held on the aquaculture of triploid *C. ariakensis* and the introduction of a non-native oyster in the Chesapeake Bay. The symposium report (Hallerman et al., 2002) identified the need for a more complete understanding of the biology and ecology of *C. ariakensis.* The following general consensus statements emerged:

- Once a non-native is introduced into an ecosystem that introduction may be irreversible;
- An uncontrolled illegal introduction could establish a reproductive, diploid oyster population;
- The non-native species could become established as a nuisance species;
- There might be competition with the native species;
- New pathogens could be introduced.

The introduction of a non-native species could have consequences for all of the Chesapeake Bay and potentially, other neighboring coastal regions. In 1993, the

Chesapeake Bay Program adopted a policy to evaluate and address proposals for first time introductions of non-indigenous aquatic species. The policy states "it shall be the policy of the jurisdictions in the Chesapeake Bay basin to oppose the first time introduction of any non-indigenous species into the unconfined waters of the Chesapeake Bay and its tributaries for any reason unless environmental and economic evaluations are conducted and reviewed in order to ensure the risks associated with the first time introduction are acceptably low." As a result of this policy, ad hoc panels have been created in 1997, 1998, 2000 and 2002 to provide advisory recommendations on proposed studies of *C. gigas* and *C. ariakensis* to VIMS and the Virginia Seafood Council.

The potential introduction of *C. ariakensis* for aquaculture in Virginia has stimulated great interest among a variety of stakeholders throughout the region. As a result of this interest and the potential implications for the Bay and neighboring coastal regions, the National Research Council (NRC) of the National Academy of Science will objectively study the potential impacts of an introduction. The NRC study will examine the ecological and socio-economic risks and benefits of open water aquaculture or direct introduction of the non-native oyster, *C. ariakensis* in Chesapeake Bay. The study is scheduled for completion by August, 2003.

The committee will address:

- How *C. ariakensis* might affect the ecology of the Bay, including effects on native species, water quality, habitat, and the spread of human and oyster diseases
- Possible effects on recovery of the native oyster
- Potential range and effects of the introduced oyster within the Bay and in neighboring coastal areas
- The adequacy of existing regulatory and institutional frameworks to oversee and monitor these activities
- Whether the breadth and quality of existing research on oysters and on other introduced species, is sufficient to support risk assessments of three management options
  1. no use of non-native oysters
  2. open water aquaqulture of triploid oysters, and
  3. introduction of reproductive diploid oysters
- Recommendations for additional research priorities

Once the committee has completed their study, additional discussions will be necessary to consider how the results affect the management of *C. virginica*.

VII. Monitoring & Information Management

An important part of the planning process is coordinating how the oyster partners will monitor their projects, process the data, and make the data available to each other and other interested groups. This process is necessary for assessing the status of the oyster resource, tracking the restoration effort, and evaluating management strategies and actions. There are several steps in coordinating data management. The first step is to define the critical data elements and to collect the data. The second step is to maintain a centralized database or databases, and identify the people/organizations responsible for maintaining the data. The next step is to analyze the data and integrate the various project results into a comprehensive view. The last step is to make the data and results accessible to the oyster partners, the scientific community and the general public.

Oyster monitoring programs already exist in Maryland and Virginia. Monitoring results (eg. mortality; disease prevalence & intensity; spat settlement) are currently used to guide restoration and repletion activities. Efforts to improve the existing monitoring programs have occurred throughout the history of oyster management in the Bay (see Site Suitability Criteria, Section 2, Chapter 1). The development of an integrated monitoring program by Maryland and Virginia is in progress as a part of the stock assessment project (CBSAC Rept. 2001). With the proposed scope of restoration activities over the next decade, monitoring needs will increase. Over time, monitoring programs should be periodically reviewed and adapted to the changing needs of restoration and assessment.

Monitoring the oyster stock and oyster restoration projects requires at least two different spatial considerations, a baywide approach and a site-specific approach. This chapter provides general guidelines for site-specific monitoring; describes the current baywide monitoring programs; and recommends mechanisms to make data available to the oyster partners, the scientific community and the general public.

Project Site Monitoring

The general framework for monitoring is based on standard scientific methodology. Each oyster project must state its purpose or hypothesis, followed by a statistically valid monitoring design to address the hypothesis. In addition, each project should identify how it will contribute to the overall objective of increasing oyster biomass. All oyster projects/sites will be tracked but at different levels of intensity and for varying lengths of time. As oyster populations in sanctuaries and open/closed areas change over time, the level of monitoring may also change over time.

Baseline Monitoring

Sample once per year – October/November.
Number of samples dependent upon the variability of samples.
Parameters:

- Abundance

- Mortality
- Disease (Dermo only) – prevalence and intensity
- Size
- Salinity
- Temperature
- DO
- Additional parameters as needed to evaluate project (i.e., success criteria listed in the project plan)

Standard Monitoring
Applies to most Oyster Sanctuaries and Open/Closed areas.
Sample two times per year – October/November, April/May.
Number of samples dependent upon the variability of samples.
Parameters:

- Abundance, density and size distribution
- Mortality
- Disease (Dermo only) – prevalence and intensity; archive for MSX/other
- Spat settlement
- Salinity
- Temperature
- DO
- Additional parameters as needed to evaluate project (i.e., success criteria listed in the project plan)
- Videography (optional)

Enhanced Monitoring
Applies to selected Oyster Sanctuary and Open/Closed project sites.
Three times per year – October/November, April/May, July/August
Number of samples dependent upon the variability of samples.
Parameters:

- Abundance and size distribution
- Mortality
- Disease (Dermo only) – prevalence and intensity; archive for MSX/other
- Spat settlement
- Salinity
- Temperature
- DO
- Additional parameters as needed to evaluate project (i.e., success criteria listed in the project plan)
- Videography (if available)
- Fouling organisms
- Benthic community diversity
- Finfish abundances
- Sedimentation
- Larval production (only during appropriate seasons)

Measuring Stock Status

The Chesapeake Bay Stock Assessment Committee (CBSAC) has funded a research effort to estimate the oyster population size in the Bay. This research endeavor is in progress and has, to date, collected the data and determined a method for estimating the oyster population. The results of this effort will provide the means to track progress towards the tenfold objective; establish a quantitative standard for managing the commercial harvest; and track the results of habitat restoration efforts. The 1994 oyster population estimate (which is inclusive of the 1993/1994 commercial harvest season in MD) will be used as the baseline for estimating progress toward the tenfold objective. Since the oyster population will naturally change in abundance from year to year, determining the effects of fishing, disease, reproductive success, and environmental factors such as temperature and salinity are important for developing commercial harvest strategies.

Action 7.1

A) Utilize the results of the oyster stock assessment as an estimate of oyster abundance in the Bay.
B) Use as the 1994 biomass value as a baseline to track progress towards the ten-fold objective.

Maryland Fall Oyster Survey

The Maryland Fall Oyster Survey collects data on oyster spat settlement, mortality, and disease prevalence in Maryland's portion of the Bay using a dredge. Conducted by the Maryland Department of Natural Resources, the survey includes monitoring at natural oyster bars, seed production grounds, seed oyster transplantation locations, and fresh shell plantings. This survey is the primary source of data used for management and restoration of the oyster resource in Maryland.

Virginia Spatfall, Dredge, and Patent Tong Surveys

The Virginia Institute of Marine Science, in cooperation with the Virginia Marine Resources Commission, performs annual Spatfall, Dredge, and Patent Tong Surveys to assess oyster populations in the Virginia portion of the Bay. Data from the Spatfall Survey are used to produce an annual index of oyster settlement and recruitment. The Dredge Survey monitors the status of the public oyster fishery by assessing trends in oyster growth, mortality, and recruitment. The Patent Tong Survey provides quantitative estimates of oyster standing stocks. All three surveys provide data to support management and restoration of oysters in Virginia.

Integration of Data from Restoration Projects

As sanctuaries and special management areas increase in size and number over time, it will be important to integrate project-specific monitoring results with those of the large-scale oyster surveys. The large-scale state surveys may not reflect oyster increases within these special management areas. The CBSAC oyster stock assessment project is developing methods for integrating baywide data and will develop monitoring recommendations for the special management areas.

Action 7.2

Conduct monitoring programs that are consistent in terms of sampling procedure, timing of sampling, types of data collected, and analysis and provide the results to a central database or databases.

Action 7.3

Establish a Technical Committee to develop data management guidelines for handling the oyster data. The following topics will be included: document each jurisdictions data bases; determine what parameters will be in centralized form; what data questions/queries will be needed on a routine basis; what are the data responsibilities of each oyster partner; what are the analytical needs; and how will the data be distributed.

Action 7.4

Develop and maintain a database to track oyster restoration projects and provide web-based access. Examples of the types of information that will be included in the centralized database(s) are:

- Summary of past and current projects, locations (maps), contacts
- On-line access to Project Tracking Database, with query function so viewers can search for relevant information.
- On-line access to data, similar to other living resources data currently available through the CBP web site.
- Oyster Stakeholders Network (OSN):
    - Subscription options
    - Submission of information to be disseminated through the Network
    - Archive of previous OSN bulletins or notices

Stakeholder inclusion is an important component of this plan because the success will depend on the support and involvement of all oyster constituencies. The following stakeholder groups have been identified for specific attention: watermen, growers, processors, retailers, sportfishermen, and environmental volunteers.

Action 7.5

The Chesapeake Bay Program will conduct an annual oyster symposium in order to:

- Review of results from projects and monitoring conducted in the previous year
- Recap plans for the upcoming year
- Re-evaluate and revise the Comprehensive Oyster Plan in light of new knowledge

The annual review symposium will be a forum for partners to exchange ideas and come to consensus on restoration strategies and methods. The format of the meeting will include both plenary sessions for presentations and discussions, as well as break-out sessions for state-level planning. Partners and stakeholders invited to the symposium will include, at a minimum, those groups listed as partners and stakeholders in Appendix 1. The symposium will be organized and hosted by the Chesapeake Bay Program and funded by one or more of the federal partners. The first annual review symposium will be held in January/February, 2004.

Conclusion

The COMP is a guide to focus and coordinate the multiple oyster partners in rebuilding the native oyster population in Chesapeake Bay. The objectives defined in the plan to increase oyster biomass and rebuild habitat are lofty in scope and ambition. The obstacles and limitations to achieving the objectives are immense, especially in relationship to disease. There are no easy and quick answers to the disease problem. Environmental factors in which the oyster partners have very little control, will play a major role in the success of the rebuilding effort.

The second part of the Comprehensive Oyster Management Plan provides guidance on specific steps that should be taken to implement any type of oyster restoration project within Chesapeake Bay. The purpose of this chapter is to standardize the project planning, project site evaluation and reporting processes. This guidance applies to any oyster restoration project including but not limited to sanctuary, special management areas, and state repletion programs. The lead agencies responsible for ensuring compliance with these procedures are Maryland Department of Natural Resources and Virginia Marine Resources Commission. This guidance applies to the following groups and any other group proposing oyster restoration activities:

- Community associations or watershed groups
- Non-government organizations
  Examples: Chesapeake Bay Foundation, Oyster Recovery Partnership, Potomac River Fisheries Commission, Maryland Watermen's Association, Living Classrooms Foundation, Virginia Institute of Marine Science, University of Maryland and other academic institutions
- Government agencies

Examples: Virginia Marine Resources Commission, Virginia Department of Environmental Quality, Maryland Department of Natural Resources Army Corps of Engineers, National Oceanic and Atmospheric Administration

SECTION 2

I: PROJECT PLANNING GUIDELINES

Project Plan Content

A written project plan will be required for all proposed projects, regardless of whether they are conducted by state, federal, non-profit, or private groups. Proposed projects can include multiple sites in the project plan. In preparing the plan, project proponents should follow the actions and recommendations laid out in this chapter and elsewhere in the Comprehensive Oyster Management Plan and provide justification if the recommendations are not followed. The types of information that should be included in project plans are listed below.

Required Information

- Project objective(s)
- Project design
- Site location (latitude and longitude)
- Designation status (i.e sanctuary, reserve)
- Criteria used to assess site suitability
- Construction specifications and methods
- Source of live oysters to be planted, planting density, and post-planting target density
- Disease management protocols
- Success criteria and monitoring protocols
- Data management including communication with Data Management Technical Committee
- Primary contact person with contact information
- Other partners involved
- Estimated cost

Additional Information

As part of the planning phase, these projects must compile spatial data in a Geographic Information System (GIS) and perform an assessment of site suitability. Relevant data layers may include but not limited to bathymetry, substrate type, sub-surface bottom structure, previous shell or oyster plantings, charted oyster grounds, harvest areas, other projects in the area, water quality, and disease prevalence. Projects should focus on the identified (Chapter IV) priority regions to conduct oyster restoration activities and the centralized database, constructed by the Database Management Technical team (Action 7.4, 7.5), should be utilized to convey this information to interested parties. Additionally, the project plan should include a brief description of the GIS maps and a mechanism should be in place to keep these maps current to reflect changes made to the project plan.

Project Review Process

The purposes of the project review process are to:

- Facilitate coordination among groups by informing all partners about projects in advance of project implementation;
- Provide the opportunity for partners to share information, suggest changes to improve proposed projects, and identify opportunities for collaboration and cost-sharing; and
- Review the logistical and technical competence of proposed projects to ensure the best use of limited resources and materials.

The review processes for Maryland and Virginia are slightly different. Project proponents should adhere to the process for the state in which the project will take place.

Maryland

1. Establish initial contact with the MDNR Shellfish Division in order to 1) notify them of the proposed project, and 2) receive assistance and advice on topics such as project location, available data, and potential collaboration with other partners. It is vital that the Shellfish Division is aware of every project conducted in Maryland waters even if MDNR is not a partner in the project. Contact: MDNR Shellfish Division

2. Submit project plan to MDNR Shellfish Division and the Maryland Oyster Roundtable Steering and Scientific Committee for review. The Shellfish Division reviews projects for technical competence, regulatory and legal issues, user conflicts, and bottom access issues. The Steering and Scientific Committee provides a technical review of projects and assesses them for scientific validity to ensure that the objectives, site selection, methods, monitoring, etc are consistent with the Maryland Action Plan, the Comprehensive Oyster Management Plan, and prevailing science.

3. Submit permit applications to the appropriate agencies, if needed. Permits are required for:
    - Any use of non-shell material (alternative materials)
    - All medium to high relief reef base construction projects that create an obstruction in the water column and may impact navigation
    - Water column (off-bottom) aquaculture
    - Invasion or excavation of the bottom

    Permitting agencies include the Maryland Wetlands Administration and the Baltimore District of the Army Corps of Engineers (COE). The Maryland Department of the Environment (MDE) handles the permit for the state but they are issued through the Wetlands Administration. To apply for a permit MDE or the COE should be contacted. The Maryland Historical Trust, U.S. Fish and Wildlife Service, MDNR, EPA, and NOAA provide technical input and advice to guide the permit agencies. Maryland Historical Trust addresses archeological concerns and NOAA, USFWS, MDNR, and EPA evaluate potential impacts to fish, SAV, and other resources. EPA addresses impacts on the physical, chemical, and biological integrity of the waters.

The permitting process generally takes four to six months and potentially longer if environmental or archeological surveys are required. Permit applications should be submitted to the permitting agencies as early as possible to avoid delays. All permits must be obtained before project implementation can occur.

4. Revise the project plan based on comments from the MDNR Shellfish Division and Maryland Oyster Roundtable Steering and Scientific Committee.

Virginia

1. Establish initial contact with the VMRC Conservation and Replenishment Division in order to 1) notify them of the proposed project, and 2) receive assistance and advice on topics such as project location, available data, and potential collaboration with other partners. It is vital that the Conservation and Replenishment Division is aware of every project conducted in Virginia waters even if VMRC is not a partner in the project. Contact: VMRC, Conservation and Replenishment Division

2. Submit project plan to VMRC for review in cooperation with Virginia Institute of Marine Science, Department of Environmental Quality, and Army Corp of Engineers, Norfolk District. VMRC, DEQ, and ACOE review each project for technical competence, regulatory and legal issues, user conflicts, and bottom access issues. VIMS provides a technical review of projects and assesses them for scientific validity to ensure that the objectives, site selection, methods, monitoring, etc are consistent with the Comprehensive Oyster Management Plan and prevailing science.

3. Submit permit applications to VMRC, if needed. Virginia has a Joint Process Permit, in which VMRC acts as a clearinghouse and circulates permit applications to DEQ and ACOE for review and approval. The request for a permit should be submitted four to six months in advance to prevent construction delays.

4. Revise the project plan based on comments from the four reviewing agencies

Site Selection

Proper site selection is essential to project success and without proper evaluation project objectives may not be met. A series of steps should be followed when evaluating a location as a potential site for an oyster project. The preliminary step in identifying a potential restoration site is to consult either the Maryland Priority Restoration Area maps or the Virginia Oyster Restoration Plan, each detailed in Chapter IV, for determination of suitable habitat in a given area. The next step of the process is to “know” the bottom of the site being considered. A bottom survey will provide the necessary information and should be done in a manner that enables determination if a site is suitable to achieve the desired project objectives and meets the below Site Suitability Criteria. The final step is to assess the information gathered in the site survey to make a final determination of whether the site complies with the Site Suitability Criteria and the project’s objectives.

Site Suitability Criteria

All projects in sanctuaries, special management areas and repletion areas need to utilize the site suitability criteria when determining the site location of an oyster project. The following are minimal criteria that must be met for a given oyster project, unless justification otherwise is provided in the project plan.

1. Hard bottom - preferably with at least some shell. A bottom that will support single shells should support oysters. Firm sandy muds and muddy sands are good; even better if they contain 10% shell and/or rocky material. Soft mud (>80% silt and/or clay) or shifting sand (>80% sand) are not suitable. These unsuitable bottoms will generally remain so even if shells are planted because the shells sink into the mud or are buried by the shifting sand.

2. Presence of shell - the presence of shell in the top several inches of sediment indicates that oysters once lived there and this is a good indication that this location may be suitable. If oysters have never lived there (and there is no evidence that they did) the site will be considered unsuitable. Exceptions could be considered based on project objectives and justification. For example, hard bottom may be considered for special disease projects when trying to establish disease-free area.

3. History of wild spat settlements - projects will be placed in areas of high or low spat settlement dependent upon project objectives. Optimal locations will have sufficient spat settlement to facilitate the development of a self-sustaining population. Even low to moderate occasional spat settlements may build up an area over time, but areas with no history of spat settlement are not suitable since a population put there would probably not be self sustaining.

4. Adequate Water Flow - water flow is critical to bringing food and oxygen to the oysters and removing silt, feces and pseudofeces which can bury and smother the oysters.

5. Sedimentation Rate – an area is unsuitable if the rate of sedimentation outpaces oyster growth. If sedimentation occurs too rapidly then an oyster population cannot be sustainable due to degraded habitat and lack of substrate for oyster larval settlement.

6. Water depth - projects should occur in areas <20ft (7.6 m) but not in areas impacted frequently by low dissolved oxygen (DO) events. No projects should occur in waters >30 ft as these area have increased chances of low DO events. All projects should refer to the Dissolved Oxygen Criteria as documented in the Water Quality Criteria under development.

7. Salinity – the project objectives as identified in the project plan will determine at what salinity a specific project will be placed. Due to disease pressure, there are strategies in Chapters 3, 4 and 5 for determining what the salinity ranges for sanctuary, special management and repletion projects should be.

Evaluation

Evaluation of the data collected during the bottom survey to assure compliance with the Site Suitability Criteria is the final step of the site selection process. This evaluation needs to be detailed in the Project Plan. The assessment is critical to proper site location and without proper evaluation the project objectives may not be met. An analogy to this process can be thought of in terms of surveyor out to assess whether a building can be put on a site; the surveyor must come back with plans, statistics, and drawings. In turn, the project proponent must do the same through the assessment and evaluation. Given the present technology, knowledge, and resource limitations oyster projects should not be placed in sub-optimal locations due to lack of a proper site assessment or poor site selection.

Project Monitoring

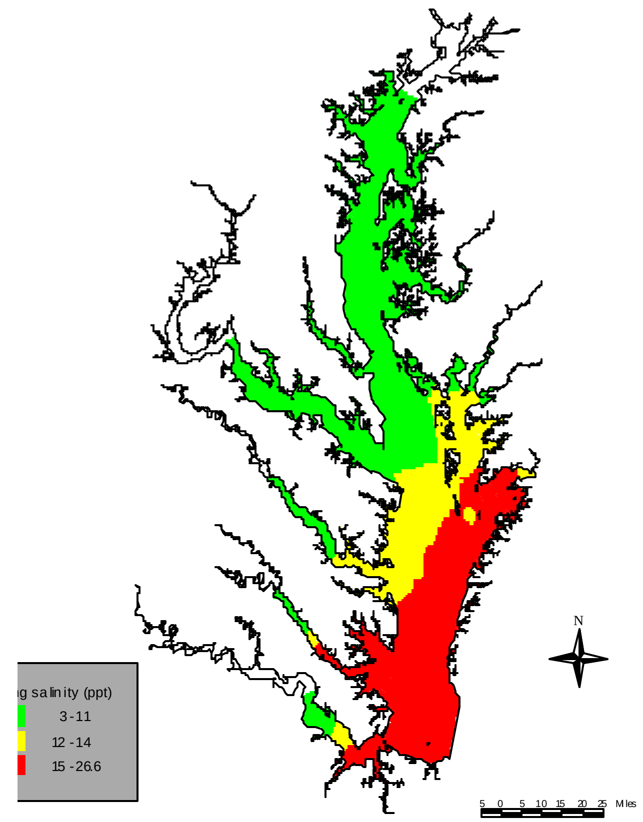
Refer to Chapter VII for monitoring considerations.

II. Implementation

This section of the plan is currently in development but upon completion will include detailed tables listing all of the identified actions within the document. The tables will include each action listed in numerical order, identification of what agency or agencies will be responsible for implementation of that action and the timeframe for completion where appropriate of each action.

Figures

Figure 1. Spring Salinity - 10 year Average (1990-1999)
(Apr. through June, at a depth range of 10 -20 feet)



igure 2. Summer Salinity - 10 year Average (1990-1999)
(July through Sept., at a depth range of 10 - 20 feet)

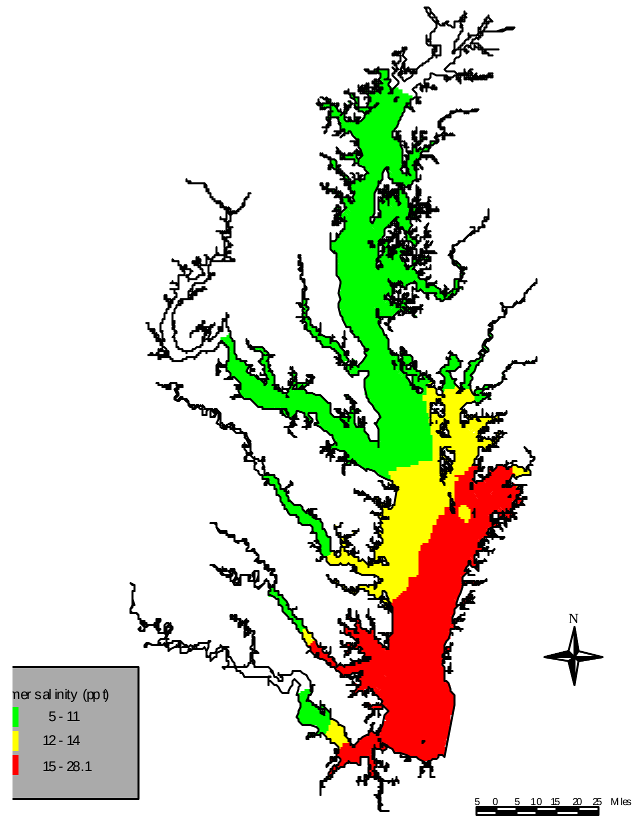


Figure 3: History of commercial oyster landings in Chesapeake Bay

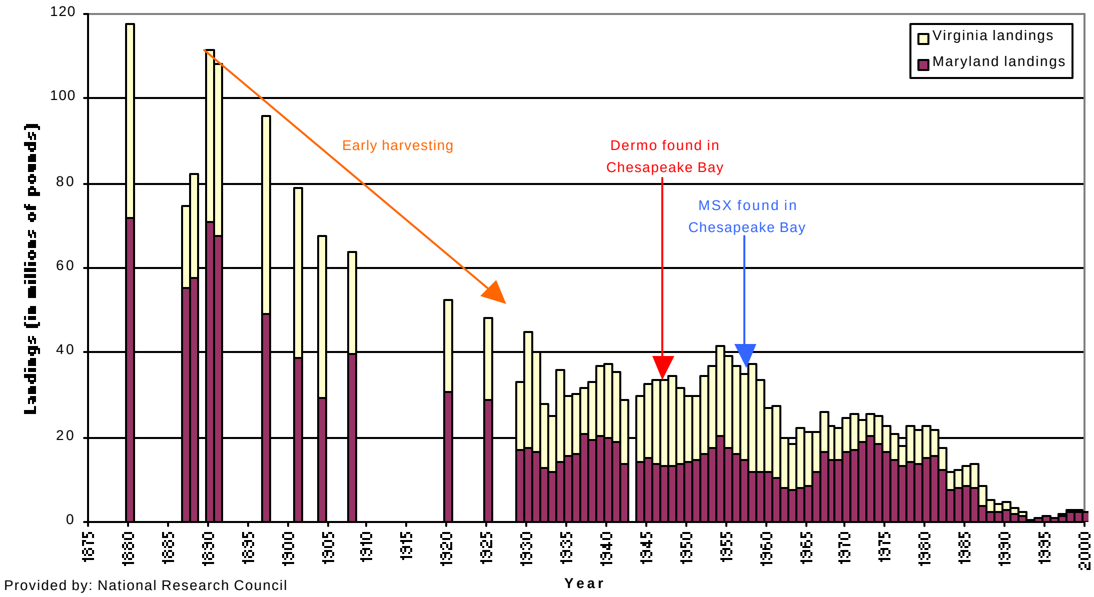


Figure 4: Chesapeake Bay Landings vs. Unadjusted Dockside Value

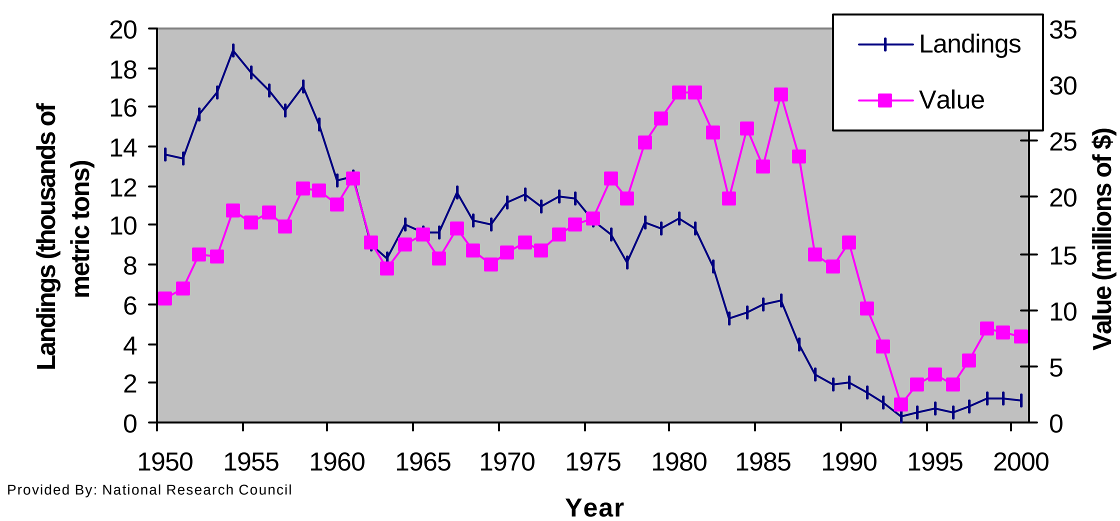
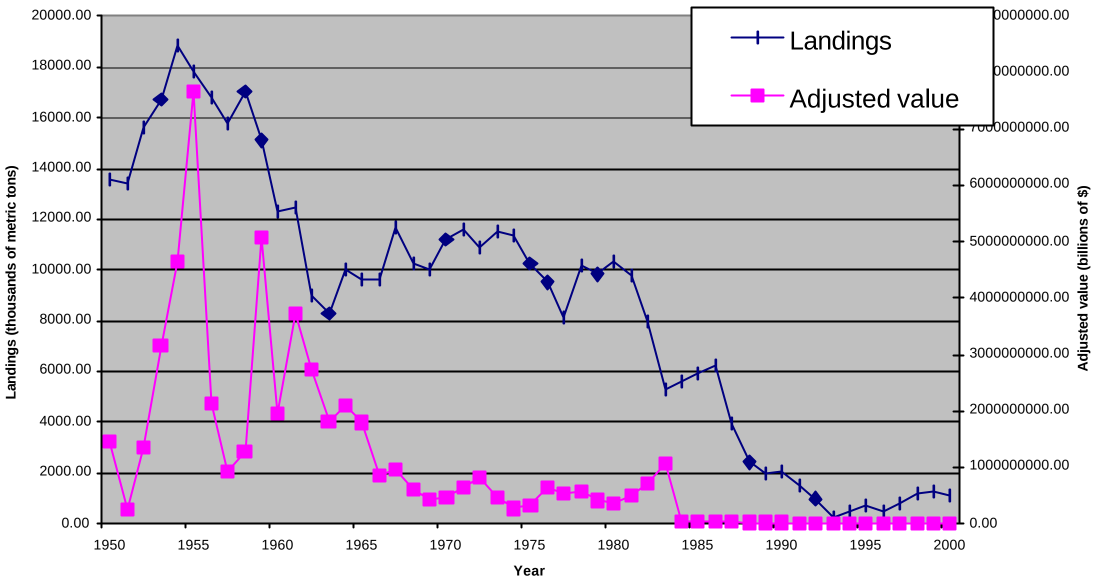


Figure 5: Chesapeake Bay landings vs. adjusted dockside value



Provided By: National Research Council

Glossary

Development of a common language is fundamental to any collaborative undertaking. Terms like oyster reef, bar, and ground or restoration, rehabilitation, repletion, and replenishment have been used interchangeably in the past. The purpose of this section is to clarify common terms used by the oyster restoration partners in order to avoid confusion in the future. These terms are italisized when they first appear in the plan.

Key Management Terms

Restoration – Returning to a former, normal, or unimpaired condition (adapted from Luckenbach et al., in press; Webster's New World Dictionary 1982). In its literal sense, restoration would imply bringing something back to its original state. In the context of oyster reef habitats and oyster populations in Chesapeake Bay, a return to the original or historical state is probably not feasible. In this document, restoration is used in a general sense to encompass the suite of objectives presented in this Comprehensive Oyster Management Plan. As a general term, restoration does not refer to any specific management activity.

Protection – Reduction or management of anthropogenic disturbance (Luckenbach et al., in press). In Chesapeake Bay, the level of protection for oysters and oyster habitat depends upon the formal designation of a given site.

Rehabilitation – Repair of damage caused by some disturbance (usually anthropogenic, but may also include natural disturbance) to recover desired ecosystem services (modified from Luckenbach et al., in press.).

Enhancement – Intervention to increase specific human or ecosystem services associated with shellfish habitat (Luckenbach et al., in press.).

Terms

Aquaculture – The propagation and rearing of aquatic organisms in controlled or selected aquatic environments for any commercial, recreational or public purpose. Specifically, oyster aquaculture is the cultivation of oysters and can be classified according to whether it occurs on or off the bottom:

> On-bottom –Cultivation that involves planting directly on the bottom without containment, and requires a lease issued by the state
>
> Off-bottom– Cultivation that involves the use of structures (e.g., floats, racks), and often requires both federal and state permits.

Baylor oyster bar/ground – Historic oyster bar/ground in Virginia charted by the Baylor surveys of 1894 and revised periodically by the General Assembly.

Biomass – The total weight or volume of a species. The current method of estimating oyster biomass is….

Biogenic – From bio- (life) + genesis (creation or formation). In the context of oyster reefs, biogenic refers to the creation of the physical structure of the reef by living organisms, especially oysters.

Bottom rehabilitation – (also oyster habitat rehabilitation) Repairing damage to bottom habitats within oyster grounds caused by disturbances such as harvest and increased sedimentation rates. In Chesapeake Bay, this type of rehabilitation is focused on increasing the amount and quality of substrate suitable for oyster settlement, survival, and/or growth.

Broodstock – The group of adult (reproductively mature) oysters. Oysters in Chesapeake Bay typically become reproductive at 1 ½ inches (varies with location), which is below the current minimum market size of 3 inches. Larger oysters (3-5 inches) are typically more fecund then smaller oysters

Commercial aquaculture – The propagation, rearing and/or grow out of animals to be sold, traded, bartered, offered for sale or marketed to others for financial considerations or remuneration

Cultch – Any material, especially oyster shell, which serves as a settlement substrate for oyster larvae.

Disease resistant strain - an artificially selected genetic unit that has been developed to resist disease. Under laboratory conditions, disease resistant strains become more genetically distinct and less genetically variable. Examples include strains of the native oyster called CROSBreed and DEBY.

Enhancement – Intervention to increase specific human or ecosystem services associated with shellfish habitat (Luckenbach et al., in press.).

Fecundity – Reproductive potential; specifically, the quantity of gametes, especially eggs, produced per individual over some time period. In oysters there is a strong positive relationship between oyster size and fecundity, with larger individuals producing more gametes than smaller individuals.

Harvest area – A general term, not a formal designation, referring to an area where public harvest is allowed (see Oyster Harvest Reserve and Public Oyster Ground).
Harvest Reserve – (Maryland only) A formally designated area that is managed to maximize oyster production for both commercial harvest and ecological services by

opening the reserve to harvest on a rotational basis. Protection is afforded through site-specific controls on the amount (i.e., catch size), methods (i.e., gear), and timing of harvest.

Hatchery production – The production of spat by private, state, or non-profit hatcheries to provide seed for commercial or public oyster aquaculture.

Historic oyster bar/ground – General areas where oysters once occurred, charted by historic surveys of the late 1800s and early 1900s.

Historically productive oyster bar/ground – The fraction of historic oyster ground that we believe was occupied by oysters. Productive grounds amounted to less than 100% of the total area charted because the historic oyster reefs were not continuous, but were interspersed with areas of sand and mud.

Interstitial space – Small or narrow spaces between things or parts. In the context of oyster reefs, interstitial space refers to the crevices and cracks within the solid matrix formed predominantly by living oysters and dead oyster shells. These spaces serve as refugia from threats such as predation for oyster spat and other reef-dwelling organisms.

Intertidal oyster reef – An oyster reef that extends from the sea bottom to the intertidal zone, the top of which occasionally breaks the water surface during low tide. Intertidal reefs can occur along the shoreline, or as high relief (6-8' height) structures in deeper water. Historically, intertidal oyster reefs in Chesapeake Bay occurred primarily in Virginia waters.

Leased Oyster Bottom – A formally designated area that has been leased by the state to a private interest for on-bottom commercial oyster aquaculture. In Maryland, these areas are restricted to areas outside charted oyster bars or lacking commercially harvestable quantities of clam (i.e., usually barren bottom). In Virginia, these areas can include barren bottom or historic oyster grounds.

Market Oyster – An oyster 3 inches or more in length available for legal harvest by the public commercial and recreational fishery.

Natural Oyster Bar (NOB) – (also charted oyster bar) In Maryland this term has a legal definition, which is generally similar to the definition given here for oyster bar/ground, and is used in a regulatory context. This term is not used in Virginia.

Noncommercial Aquaculture – Grow out of animals strictly for personal or private consumption or use, specifically for oysters, cultivation by the state or non-profit groups to enhance the public resource.

Oyster bar/ground – General areas where oysters once occurred (see historic oyster bar/ground) or presently occur. These areas are represented on charts maintained by the states of Maryland and Virginia for the purposes of management and enforcement of fishery regulations; they may or may not be a true delineation of current oyster habitat.

Oyster gardening – The cultivation of oysters by private citizens for personal consumption or restoration purposes. This activity is distinctly smaller in scale than commercial aquaculture and is typically conducted at private docks.

Oyster planting – (also oyster stocking, oyster seeding) Placing live oysters (usually seed, but sometimes adults) on the suitable bottom.

Oyster reef – A biogenic structure created and stabilized by an aggregation of living oysters and other sessile (permanently attached) organisms, which provides habitat for a variety of other organisms. Living oysters reefs typically have average densities of $\geq$100 oysters/m^2, although a truly "healthy" oyster reef would have densities of $\geq$400 oysters/m^2 covering at least 50% of the reef surface. A biologically important aspect of oyster reef architecture is the amount and nature of interstitial space. Formation and continued existence of an oyster reef requires conditions favorable for oyster recruitment, survival, and growth, as well as the absence physical disturbances to the integrity of the reef structure. Oyster reefs are not defined by any particular shape or size, but can be classified by certain gross morphological features such as vertical relief (height or elevation) relative to the sea bottom and the water surface:

Protection – Reduction or management of anthropogenic disturbance (Luckenbach et al., in prep). In Chesapeake Bay, the level of protection for oysters and oyster habitat depends upon the formal designation of a given site.

Public Oyster Ground – Virginia designation for oyster grounds open to the public fishery, generally including all charted oyster grounds except areas designated as Oyster Sanctuary, Oyster Harvest Reserve, or Leased Bottom. Harvest on Public Oyster Grounds is regulated through traditional state fishery regulations.

Recruitment – Addition of new individuals to some group. In the context of oysters, two interpretations are relevant:

> Ecological – Survival beyond the larval and spat stages, at which point individuals become ecologically functional (e.g., water filtration, reef building) members of the oyster population.
>
> Population – Survival to reproduction (i.e., typically at 1 ½ inches in size), at which point individuals become genetically functional members of the oyster population.

Reef base – A foundation of material (e.g., shell, alternative materials) placed in such a manner and location, and typically accompanied by other management activities (e.g., oyster planting), as to encourage the formation of an oyster reef.

Rehabilitation – Repair of damage caused by some disturbance (usually anthropogenic, but may also include natural disturbance) to recover desired ecosystem services (modified from Luckenbach et al., in press.).

Repletion – Oyster planting in specific areas for commercial harvest

Resistance - the relative ability of an organism to avoid infection or to withstand the effects of disease (Ford & Tripp 1996)

Restoration – Returning to a former, normal, or unimpaired condition (adapted from Luckenbach et al., in press; Webster's New World Dictionary 1982). In its literal sense, restoration would imply bringing something back to its original state. In the context of oyster reef habitats and oyster populations in Chesapeake Bay, a return to the original or historical state is probably not feasible. In this document, restoration is used in a general sense to encompass the suite of objectives presented in this Comprehensive Oyster Plan. As a general term, restoration does not refer to any specific management activity (see definitions under protection, rehabilitation, and enhancement for terms related to specific management activities).

Sanctuary – A formally designated and marked area that is permanently protected by a complete prohibition on the harvest of shellfish species (clams and oysters)

Seed (noun) – oysters usually less than one year in age (spat) used in oyster planting. Size at planting is typically less than one inch, but if older year classes are used as seed, then they may be up to 1.5 inches. Seed may be classified according to source of production.

> Hatchery seed – Seed oysters produced by a hatchery. Hatchery seed can be produced from a variety of broodstock sources. Hatchery seed are very young when planted, usually less than 4 weeks and they are usually less than 1 inch in size.
>
> Wild seed – Seed oysters produced by natural reproduction of wild populations. Spat settle upon on dredged shells that are planted for the purpose of creating the seed, within areas known as Seed Areas. Spat comprise the majority of the wild seed used in Maryland and are between .5 inches to 1 inch, though some may be smaller and larger.

Seed (verb) – See oyster planting

Shell planting – Placing clean oyster shell on the bottom.

Spat –Juvenile (not yet reproductive) oysters, less than one year old, typically ranging in size up to 30 mm. Oysters typically become reproductive in their second year of life, at which time they are usually 1 ½ inches in size and are predominantly males.

Spat settlement – (also spatfall, spatset) Metamorphosis of planktonic oyster larvae into juvenile oysters (spat), during which the larvae permanently attach to the settlement substrate (cultch).

Special Management Area -

Specific Pathogen Free (SPF) – Refers to oysters that have been tested and found to be free of certain specific pathogens, namely MSX and Dermo.

Stock – The natural genetic unit of a population determined by its isolation from other populations. Stocks are an evolutionarily determined entity. For example, oyster (*Crassostrea virginica*) stocks from northern New England, mid-Atlantic, and Gulf coast vary genetically from one another. For the purpose of this document, we consider all of Chesapeake Bay oysters to be one stock.

Subtidal oyster reef – An oyster reef that extends some height above the surrounding bottom, but does not reach the intertidal zone. Subtidal oyster reefs can be further categorized as:

> Low relief – From >0 to 1 foot in height.
>
> Medium relief – From 1.5 to 6 feet in height.
>
> High relief – Over 6 feet in height. High relief subtidal oyster reefs probably did not historically occur in Maryland waters.

Transplantation – Moving live oysters from one location to another.

Yates oyster bar/ground – Historic oyster bar/ground in Maryland charted by the Yates Oyster Survey of 1906-1912, and its amendments.

Wild stock - oysters that are genetically unchanged from their natural state. Oysters in Chesapeake Bay are more or less wild because of several human activities: movement of oysters within the Bay; movement of oysters into the Bay from other areas (eg. Louisiana); and the introduction of disease resistant strains.

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Appendices

Appendix 1. Partners and Stakeholders

This appendix identifies the major players involved in oyster restoration and management in Chesapeake Bay, and provides general descriptions of their missions and activities. These groups are organized under the following categories:

- Federal Agencies
- State Agencies
- Multi-partner Groups
- Non-profit Organizations
- Academic and Research Institutions
- Private Stakeholders

Federal Agencies

Army Corps of Engineers (ACOE)

The U.S. Army Corps of Engineers is a service organization that provides engineering and construction support to the Army, other defense elements, and the American people. The environmental restoration mission of ACOE includes examining the condition of existing ecosystems, or portions thereof, and determining the feasibility of restoring degraded structure and function to a less degraded, natural condition. This includes identifying a plan, or plans, that create the maximum amount of environmental benefits by the most cost-effective means and then implementing the chosen plan.

The ACOE's restoration plan focuses on contributing to the goals of restoring 10% of the Bay's historically productive public oyster grounds as oyster sanctuaries and increasing the biomass of oysters tenfold by 2010 from a 1994 baseline. The role of the Corps will be centered on cost effective planning, and then construction and rehabilitation of oyster reef habitat of various heights and types in cooperation with a local sponsor. The Corps' recommended plan will be determined by the best available scientific and economic information, and focused primarily on achieving the restoration of native oysters by the most cost effective means.

Environmental Protection Agency (EPA)

The EPA is the lead federal agency representing the federal government in the Chesapeake Bay Program. The agency provides funding for staff for the Living Resources Subcommittee and for bay wide fisheries management planning and coordination as well as for research, habitat restoration, ecosystem modeling and ecosystem monitoring, data management, and public communication. EPA has ultimate responsibility for implementation and enforcement of the Clean Water Act, including oversight of state and federal programs that regulate pollution discharge. They also play a key role in the environmental review of federal project plans (e.g. ACOE plans), and federal permits (e.g. shell dredging and discharge permits) for consistency with the National Environmental Policy Act.

National Oceanic and Atmospheric Administration (NOAA)

NOAA's involvement in oyster restoration activities is anchored by technical staff at the NOAA Chesapeake Bay Office (NCBO). This office provides restoration planning, coordination, funding, and technical assistance to entities in each state. NOAA provides funding for oyster population and habitat restoration and has funded restoration projects scaled from local community-based activities, to large-scale, multi-river efforts with emphasis on both restoring oyster habitat and oysters for harvest, including employment of various strategies to further the science of oyster restoration. NOAA also funds initiatives to increase hatchery efficiency and capacity and oyster disease research including development of specific pathogen free oyster strains. Technical assistance is also provided through cooperative projects for monitoring and project result validation. They also provide ship based charting technology, which may be utilized for large-scale, bay-wide bottom substrate mapping to aid in oyster restoration objectives.

State Agencies

State agencies in both Maryland and Virginia are responsible for regulating the use of the bottom resource, and for managing the public oyster grounds on behalf of the citizens of each state. The various state agencies are responsible for a wide range of actions regarding oysters, including: fishery management (season, daily limits, licensing, gear, cull size, etc); resource restoration including establishment of special management ares (shell and seed programs, bottom cleaning, etc); regulation of bottom uses; permitting and leasing for restoration projects and aquaculture; protection of public health; monitoring oyster populations and water quality; disease analysis; coordination of restoration partners; and providing technical assistance to other agencies and organizations. The states also issue permits and contracts for the dredging of buried shell, and thus control access to this resource.

Maryland Department of Natural Resources (MDNR)

MDNR is the state agency responsible for oyster restoration and management. Maryland law authorizes the department to "take measures which in its judgement seem best calculated to increase the productivity or utility of any part of the natural oyster bars of the state. To fulfill this mission, MDNR's Shellfish Division conducts two programs to increase the economic and ecological benefits of oysters. The Oyster Restoration Program restores oysters for ecological benefits and the Oyster Repletion Program restores oysters to enhance the fishery. MDNR regulates harvest, establishes sanctuaries and reserves, manages the acquisition of buried and fresh (i.e., shucking house) shell, conducts reef restoration within sanctuary areas, surveys and monitors the oyster population, maps bottom types, and maintains a GIS of oyster grounds, bottom types, and environmental conditions. Partners include federal, state, and non-government agencies. MDNR establishes and works closely with various committees, including county oyster committees, statewide oyster committees, and the Tidal Fisheries Advisory Commission. In addition, MDNR spearheads the Maryland Oyster Roundtable Steering Committee.

Maryland Department of the Environment (MDE)

The Maryland Department of the Environment is the state agency responsible for protecting the public health by regulating the Shellfish Harvesting Areas in Maryland waters. MDE conducts monitoring to determine whether shellfish areas are contaminated with disease-causing bacteria, and identifies approved, restricted, or conditional growing areas according to protective criteria for human consumption. The agency periodically monitors to ensure that open harvest areas are free of disease-causing bacteria. In addition to monitoring for bacteria, the agency also triennially monitors shellfish for levels of metal and pesticides.

Virginia Marine Resources Commission (VMRC)

The Department of Conservation and Replenishment within VMRC is tasked with the management and replenishment of the public oyster grounds in Virginia. The Department Chief with the assistance of an Advisory Committee develops strategies to improve and restore the public oyster grounds. Restoration activities include the spreading of cultch as oyster setting substrate, rejuvenation of old oyster beds using dredges, creation of oyster reefs for optimal oyster habitat, and the movement of oysters from seed areas to grow-out areas. In addition, VMRC is also one of the main partners in the Virginia Oyster Heritage Program and supports their mission of creating broodstock sanctuaries, enhanced harvest areas, and oyster monitoring activities. The Department systematically and scientifically monitors all the restoration activities to determine their success.

Management strategies are developed and regulations promulgated to conserve the oyster resources using season and time limits, catch limits, and gear restrictions. Conservation and Replenishment personnel also coordinate all shellfish relaying information to ensure compliance with the Code of Virginia and FDA guidelines for handling shellfish taken from condemned shellfish areas.

Virginia Department of Environmental Quality (VDEQ)

VDEQ is one of the lead agencies in the Virginia Oyster Heritage Program. Please see the Multi-Partner Groups section below for a description of that program.

Multi-Partner Groups

Several bodies have been formed to facilitate collaboration among multiple partners.

Chesapeake Bay Program (CBP)

Created in 1983, the Chesapeake Bay Program is a regional, multi-agency partnership that direct and conducts restoration of the Chesapeake Bay. Bay Program partners include the states of Maryland, Pennsylvania, and Virginia; the District of Columbia; the Chesapeake Bay Commission; the U.S. Environmental Protection Agency; and numerous advisory groups. In June 2000, the Chesapeake Bay Program partners signed the Chesapeake 2000 Agreement, which set goals for restoring and protecting the Bay and its watershed over the next decade. The oyster goal established by the new agreement is to achieve, at a minimum, a tenfold increase in native oysters in Chesapeake Bay by 2010 based upon a 1994 baseline

The CBP's Living Resources Subcommittee serves as a forum for all the partners to collaborate in the planning and implementation of oyster restoration activities throughout Chesapeake Bay. The staff of the Living Resources Subcommittee facilitates coordination of efforts bay wide, and will ensure interagency cooperation in achieving the tenfold goal. This coordination will include organizing and hosting an annual review to evaluate progress. CBP staff also will also be responsible for tracking cumulative progress toward the tenfold goal.

Virginia Oyster Heritage Program (VOHP)

The Virginia Oyster Heritage Program is a partnership between state and federal agencies, nonprofit organizations, watermen, and business groups. This partnership is administered by VDEQ's Coastal Management Program and VMRC. Major partners within the program include NOAA's Office of Ocean and Coastal Resource Management, ACOE's Norfolk District, VIMS, Virginia Sea Grant, the Virginia Environmental Endowment, the Virginia Seafood Council, and Chesapeake Bay Foundation. The program serves as a forum for integrating the activities of the various partners in order to undertake large-scale oyster restoration work in Virginia. To date, VOHP's activities have focused on the Rappahannock River, Lynnhaven River, and Tangier Sound.

The program has four major objectives: to establish sanctuaries, enhance harvest areas near established sanctuaries, monitoring on newly created reefs for success in increasing oysters, water clarity, and biodiversity and to train and provide educational materials to volunteers interested in oyster gardening (see chapter x)

As an outgrowth of the program, a non-profit organization – the Virginia Oyster Reef Heritage Foundation (see Non-profit Organizations) – was created to conduct private fundraising to support the program's goals.

Potomac River Fisheries Commission (PRFC)

The Potomac River Fisheries Commission consisting of eight members, four from Virginia and four from Maryland, works to conserve and improve seafood resources of the Potomac River. The Commission is a semi-autonomous agency, but its work and policies are coordinated closely with the Fisheries Service of the Maryland Department of Natural Resources and the Marine Resources Commission of Virginia. Fishery agencies of both states provide law enforcement on the Potomac River for the Commission. The

Commission regulates and licenses fisheries and the dredging of soft-shell clams in the Potomac River.

Maryland Oyster Roundtable and Steering Committee (MD ORT)

The Maryland Oyster Roundtable, was convened by the State of Maryland in 1993 to address how to bring oyster stocks back to economically and ecologically healthy levels. There are forty members representing commercial waterman, aquaculturists, environmentalists, legislators, scientists, and senior staff from the Maryland Departments of Agriculture, Environment, Natural Resources and the Governor's Office.

As a product of the Roundtable, a steering committee was formed with representatives from the processing industry, commercial waterman, state agencies, environmentalists and scientists to serve as the implementation branch of Roundtable. The steering committee has multiple roles, which includes serving as a forum to discuss and resolve pertinent oyster management issues and provide guidance to Maryland's oyster restoration efforts in a consensus process among stakeholders. The committee meets on average three to six times a year.

Chesapeake Bay Commission (CBC)

The Chesapeake Bay Commission is a tri-state legislative body that advises the General Assemblies of Virginia, Maryland and Pennsylvania in cooperatively managing the Chesapeake Bay. The Commission is available to provide information and advice on Chesapeake Bay issues to any member of the three General Assemblies. The Commission is also a signatory to the Chesapeake Bay Agreement. As a signatory, the Commission serves as the legislative arm of the Chesapeake Bay Program and is fully involved in all Bay Program policy and implementation decisions. The statutes that created the Commission contain explicit duties, which provide for cooperation on issues of mutual concern to the Bay states.

Non-profit Organizations

Chesapeake Bay Foundation (CBF)

The Chesapeake Bay Foundation is a non-profit, conservation organization with more than 93,000 members and offices in Maryland, Virginia and Pennsylvania. CBF's mission is "To restore and sustain the Bay's ecosystem by substantially improving the water quality and productivity of the watershed, with respect to water clarity, resilience of the system, and diversity and abundance of living resources, and to maintain a high quality of life for the people of the Chesapeake Bay region."

Oysters are considered by CBF to be a key element of any strategy to restore the Bay and has been involved in oyster protection efforts for about twenty years and actively engaged in oyster restoration for ten years.CBF has a multi-faceted role in oyster restoration. It serves as an advocate with special emphasis on lobbying for state and federal support for restoration. CBF also serves as an educator, annually teaching tens of thousands of students about oyster ecology and empowering them to contribute to restoration. Closely related is CBF's role as a facilitator for citizen involvement in restoration through its oyster gardening and volunteer programs. Finally, CBF is a catalyst for restoration through its creative partnering, targeted fundraising and innovative aquaculture and reef-building work. In these ways, the Foundation attempts to clear roadblocks to restoration and develops new approaches that help achieve the collective oyster goals for the Bay.

Oyster Recovery Partnership

The Oyster Recovery Partnership's mission is to help bring back the health of Chesapeake Bay through restoration of critical oyster resources. The Partnership was formed in 1994 by a mandate of the Maryland Oyster Roundtable.

The role of Oyster Recovery Partnership is to carry forth the objectives determined in the Roundtable Action Plan. The Partnership works with regional interest groups to create oyster sanctuaries, as well as to enhance and manage reserve areas that can be opened periodically to harvest. The Partnership relies heavily on cooperative relationships to provide specific pathogen-free seed oysters produced by the University of Maryland's Center for Environmental Science, provide information on bottom conditions for proper site selection, and to provide monitoring services. The Partnership's small staff utilizes both citizen volunteers, environmental groups and watermen to complete restoration projects, thereby integrating outreach and education with restoration work. The Partnership also works to strengthen ties with watermen by through groups such as the Maryland Watermen's Association.

Funding is provided by cooperative agreements with Maryland state agencies, contracts with the Army Corp of Engineers; grants from NOAA's Chesapeake Bay Office, Chesapeake Bay Foundation, Chesapeake Bay Trust, Campbell Foundation for the Environment, Mirant Mid-Atlantic Corporation, World Wildlife Fund, National Fish and Wildlife Foundation, numerous local community groups, and individual donations.

Virginia Oyster Reef Heritage Foundation

The Virginia Oyster Reef Heritage Foundation was created to undertake private fundraising in support of the goals set forth by the Virginia Oyster Heritage Program. The Foundation's overarching purpose is to receive private contributions in support of oyster restoration in Virginia. A major contributor to the Foundation is the Virginia Environmental Endowment, which has provided a matching grant designed to encourage private business involvement by requiring a match of two dollars from the private sector for every dollar awarded from the grant.

Academic and Research Institutions

Academic and research institutions have a multifaceted role in helping restore the Chesapeake Bay and its oyster resource. Three main contributions of these institutions are: 1) conducting research to gain a fuller understanding of oyster biology, and to develop improved methods and technologies for oyster restoration; 2) collecting scientific data by monitoring the results of many restoration projects; and 3) communicating this information to other partners to provide a sound scientific basis for management and policy decisions. There are numerous institutions that contribute to the oyster effort, the two largest institutions being the Virginia Institute of Marine Science and the University of Maryland.

Virginia Institute of Marine Science (VIMS)

VIMS conducts interdisciplinary research in coastal ocean and estuarine science, educates students and citizens, and provides advisory service to policy makers, industry, and the public. In all of their activities they seek to understand the biological, ecological, and fishery impacts on oysters and apply that knowledge toward restoration, management, and educational issues and provide research-based advisory service to the Commonwealth of Virginia. VIMS supports Virginia's oyster restoration objectives by providing spatfall, dredge and patent tong surveys and, in addition, is working on developing with the cooperation of other universities an oyster that is less susceptible to the oyster diseases MSX and Dermo.

University of Maryland (UM)

The University of Maryland provides scientific guidance and monitoring services for many of the oyster restoration projects in the state of Maryland. Researchers at UM also investigate various aspects of oyster physiology, population dynamics, diseases, and oyster reef ecology. The hatchery at the UM Center for Environmental Studies (UMCES) Horn Point Laboratory is an important producer of spat for restoration activities. Almost all spat available for restoration projects in Maryland come from the Horn Point hatchery. The hatchery is part of the UM Cooperative Extension Program, which conducts research and environmental education and outreach regarding oyster aquaculture.

Other Academic and Research Institutions

Other research institutions including the Academy of Natural Science Estuarine Research Center conduct research and monitoring related to oyster reef ecology, oyster population dynamics, and oyster disease. They also participate in Maryland and Chesapeake Bay committees charged with oyster restoration and management, and provide public education and outreach related to oyster restoration.

Private Stakeholders

Watermen and Private Leaseholders

This group includes individual watermen working public oyster beds and private groups or individuals holding leases for on-bottom oyster aquaculture. These people are represented by groups such as county oyster commissions and the Maryland Watermen's Association. There are current 731 (?) licensed oyster harvesters in Maryland, and ??? in Virginia.

Seafood Industry

This stakeholder group includes private (for-profit) hatcheries, oyster processing houses, packers, shippers, retailers, and industry associations such as the Virginia Seafood Council and the Chesapeake Bay Seafood Industries Association.

Citizens

Citizens play important roles by providing public support for restoring the oyster resource, serving as volunteers on restoration projects, and organizing community groups that work to restore oysters and improve the quality of their local waters. One activity in which citizens are becoming increasingly engaged is oyster gardening

Appendix 2: Chesapeake Bay Program Related Projects

Suspension Feeders

Currently, their is an ongoing initiative as set forth in the Chesapeake 2000 agreement to "by 2004 assess the effects of different population levels of filter feeders such as menhaden, oysters and clams on Bay water quality and habitat." In March 2002, a workshop was convened to determine the best approaches to fulfill this commitment. It is recognized that the impact of suspension feeders on water quality is dependent on population levels and distributions of species in space and time, which ultimately can be altered by management actions and natural variation in physical and biological factors.

In response to this commitment the workshop had three goals; 1) to assess current understanding of the biological and physical characteristics of the Chesapeake ecosystem needed to estimate suspension feeder effects, 2) to assess the utility of currently existing models, and 3) to identify critical features (process, organisms, model capabilities) to include in future models designed to predict effects of suspension feeders on phytoplankton and sediment in Bay waters. Stemming from these goals a four pronged approach was developed of needing monitoring and research, development of consumption estimates, use of numerical models to predict the fate of consumed nitrogen and suspended sediments and the use of models that incorporate the relative complexity of the food web.

Three different groups were formed to represent the various suspension feeders including; menhaden, benthic suspension feeders and zooplankton. Each group was tasked with making three recommendations including 1) how to estimate/model the effect of each taxa of suspension feeders on Chesapeake Bay phytoplankton given no funding or information constraints, 2) recommendation on how to predict the effect of their group of suspension feeder on phytoplankton in the best way possible given funding and time constraints and 3) develop a short list of highest priority areas of research and model development needed to reach the suggested recommendations in number 2.

The following recommendations were identified by the workshop participants for each of the three focus areas.

Data

Data needs to help fulfill the commitment include additional data for Atlantic menhaden, epibenthic invertebrates other than oysters, and soft bodied microzooplankton with the highest priority to obtain information for Atlantic menhaden.

Modeling

Consumption estimates are need for each of the above identified groups. Additional analysis, synthesis and evaluation of monitoring and relevant data sets on abundance, and spatial and temporal distributions of relevant organisms and review of scientific literature to develop consumption rates needs to occur for all three groups. In addition, there should be development of targeted models that include nutrient cycling and consumption for benthic suspension feeders and zooplankton.

Water Quality Protection and Restoration: An Innovative Approach

The Chesapeake 2000 agreement considers improvement of water quality one of the most critical elements in the overall protection and restoration of the Bay and its tributaries. A seven-jurisdiction cooperative partnership consisting of Maryland, Pennsylvania, Virginia, District of Columbia, West Virginia, New York and Delaware are currently developing a new process for setting and achieving nutrients and sediment load reductions necessary to restore Bay water quality. This new process requires the cooperative partners to establish and meet specific water quality standards instead of traditional broad percentage reduction goals.

New water quality standards will be based on three criteria: dissolved oxygen, water clarity and chlorophyll a. Additionally the criteria will differ from one region of the Bay to another in order to account for the diversity in differing habitats, however, similar habitats throughout the jurisdictions will have the same criteria to ensure consistency throughout the watershed. The habitat zones that will define the criteria include shallow water, open water, spawning and nursery areas, deep water and deep channel.

The proposed schedule for completion of the criteria and adoption of new water quality standards by the jurisdictions is as follows:

April 2003	Completion of Bay criteria and tidal waters designated uses
Summer 2003	Maryland, Virginia, Delaware, and the District of Columbia will propose new water quality standards
2004	Completion of tributary strategies by each of the jurisdictions
2005	Jurisdictions will finalize the adoption of water quality standards

Watershed initiatives supported by the Bay Program which help to further the commitment of restored water quality include:

- watershed management planning in 2/3^{rds} of the Bay's watershed
- restoration of 25,000 acres of tidal and non-tidal wetlands
- conservation of forests along streams and shorelines
- expansion and connection of contiguous forests
- creation of riparian forest buffer
- development and promotion of sound use practices